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London County Council.

BACTERIAL TREATMENT OF CRUDE
SEWAGE.

THIRD REPORT

BY

DR. CLOWES AND DR. HOUSTON.

EXPERIMENTAL INTERMITTENT TREATMENT

OF

LONDON CRUDE SEWAGE

IN

THE COKE-BEDS AT BARKING AND CROSSNESS.

PRESENTED BY

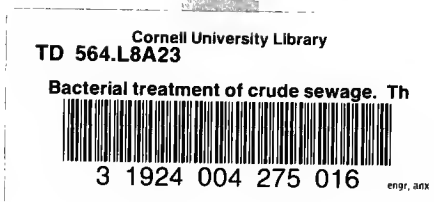
PROFESSOR FRANK CLOWES, D.Sc. (LOND.), F.I.C.

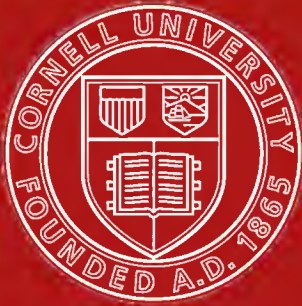
(Chief Chemist to the Council),

TO THE MAIN DRAINAGE COMMITTEE OF THE COUNCIL,

On 24th May, 1900.

(WITH APPENDIX UP TO JULY 28TH, 1900.)





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DIVISION I.—CHEMICAL AND GENERAL

BY

PROFESSOR FRANK CLOWES, D.Sc. (LOND.), F.I.C.

(Chief Chemist to the Council).

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DIVISION I.—CHEMICAL AND GENERAL.

I.—INTRODUCTORY SUMMARY.

Early in 1898 a First Report was printed by the Council on the bacteriological examination, by Dr. Houston, of London crude sewage as it arrived at the Outfalls at Barking and Crossness. This was followed by a Second Report, giving the results obtained by the chemical and bacteriological examination of the crude sewage and of the effluent from the coke-beds at Crossness. A Supplementary Report on the deposit found upon the coke of the coke-beds was issued in October, 1899.

The present Report gives a similar statement of the results obtained in the experimental bacterial treatment which has been carried out at the Northern Outfall (Barking) and of the experimental treatment carried out at the Southern Outfall (Crossness) since the issue of the last Report.

The superintendence of the chemical work has rested in the hands of Mr. E. Brooke Pike, the chemist at the Northern Outfall, and of Mr. J. W. H. Biggs, the chemist at the Southern Outfall, and the successful carrying out of the processes has been due to the careful work of these gentlemen and to the co-operation of Messrs. H. Stokoe and E. J. Beal, superintendents at the Outfalls.

The bacteriological work has been in the hands of Dr. Houston, who makes a separate statement of his results in Division II. of this Report.

The process employed at both Outfalls has been that of "intermittent contact" with frequent aëration of the coke surfaces.

The acre coke-bed at the Northern Outfall has received an effluent resulting from sewage which has been mixed with solutions of lime and iron sulphate and has then been subjected to sedimentation. The smaller coke-beds have received sewage which has not been mixed with chemicals, and which has, as a rule, not been freed from its suspended solid matter by sedimentation.

Since the cellulose substances in the suspended solid matter of the sewage are only dealt with slowly by the bacteria in the coke-bed, they tend to accumulate on the coke and to diminish the sewage capacity of the bed; they also tend to diminish the extent of purification from the dissolved organic matters of the sewage. Hence the acre bed, which receives the effluent from chemically treated and sedimented sewage, has yielded better results than the smaller experimental beds.

A very rough process of sedimentation of the sewage, without the use of chemicals, was effected at the Southern Outfall by allowing the crude sewage to flow through a large tank on its way to the coke-bed. This sedimentation considerably retarded the choking of the coke-beds.

Last Christmas an experiment was made (see page 15) on the whole of the South London sewage by allowing it to flow at a comparatively rapid pace through one of the large settling channels at the Outfall Works. In this way the larger portion of the solid suspended matter of the sewage was deposited; a portion of the effluent from this sedimentation process was treated in a small bacterial coke-tank and was found to undergo the usual amount of purification, and to furnish an almost clear and entirely inoffensive and nonputrescible effluent. No reduction in the capacity of the coke-bed occurred during the period of experiment.

From this experiment it may be inferred that simple rapid sedimentation of the crude sewage on the large scale, followed by intermittent bacterial coke treatment will furnish an effluent suitable for the lower river, together with a sludge deposit which could be dealt with in the usual way.

It seems reasonable that the experimental treatment of the sewage by rough screening, followed by rapid sedimentation without the previous introduction of chemicals, might now be attempted on a larger scale, and that by this means an effluent of much greater purity than that at present discharged might be sent into the river.

It will be seen that the general result of experience with the various coke-beds has been that they increase in efficiency as the duration of their service increases, and that some considerable period of service is necessary before they exert their maximum amount of purification of the sewage.

Dr. Houston summarises on pp. 41 to 53 the previous Reports issued by the Council, and gives on pp. 54 to 78 details of the bacteriological work which he has carried out since the issue of those Reports.

As regards the general bacteriological aspect of the treatment of London sewage, Dr. Houston gives a statement of the conclusions at which he has arrived after two years study of the problem on behalf of the Council (pp. 70 to 71). It will be seen that Dr. Houston concurs in the advisability of adopting the bacterial method of treatment of London sewage in place of the chemical treatment, and maintains that under the conditions existing in the lower river and at the Outfalls, this system of treatment would furnish a more satisfactory result. But he states that although the effluent from the bacterial beds would not lead to nuisance in the river, it would be by no means a satisfactory liquid to introduce into a part of the river which was used for drinking purposes.

II.—EXPERIMENTAL BACTERIAL TREATMENT OF CRUDE SEWAGE AT THE NORTHERN OUTFALL WORKS (BARKING).

1.—PRIMARY AND SECONDARY TREATMENT IN BEDS OF KENTISH RAGSTONE AND COKE, 5 FEET IN DEPTH.

For the purpose of these experiments four galvanised iron tanks, 4 feet square by 6 feet in depth were erected on some waste land at the liming station and were filled with material to a depth of 5 feet, and were so arranged that the effluent from the two primary tanks should drain completely into the two corresponding secondary tanks. The crude sewage supplied to the beds was obtained from a large pipe conveying sewage to the overhead lime tank, and was raised by means of a portable auxiliary pump. This pump was stopped for a few days periodically for cleaning, and on these occasions the bacteria beds could not be filled.

On the 21st of July, 1898, it was suggested that in series I. the first tank should contain a coarse bed of large coke and should discharge its effluent into a fine bed of small coke. Series II. should consist of a coarse bed of large pieces of Kentish ragstone, and should discharge its effluent into a fine bed of the same material. It seemed desirable to experiment with the Kentish ragstone, on account of its great durability and its acid-neutralising power.

It seemed probable that the calcium carbonate in the ragstone would furnish a base for the neutralisation of the nitric acid formed by the bacterial action.

The material employed in the two coarse primary beds of coke and ragstone was of such a size that the pieces would pass a 4-inch mesh and be rejected by a $\frac{1}{2}$ -inch mesh. The material in the two fine beds was of such a size that it would pass a $\frac{1}{2}$ -inch mesh and be rejected by a $\frac{1}{16}$ -inch mesh.

The procedure was as follows—

The two coarse beds were filled with crude sewage simultaneously and as quickly as possible to a level with the top of the solid material; the beds were allowed to remain full for two hours, and were then drained into the fine beds. These remained full for two hours, and were then drained off. During the outflow of the effluent from each bed it was sampled every few minutes. These samples were mixed, and the average liquid thus obtained was subjected to analysis. The crude sewage with which the primary beds were filled was sampled and examined in a similar manner.

The beds were first filled with crude sewage on the 22nd of September, 1898, and their capacity was ascertained a week later by the careful measurement of the effluent while they were being emptied. On the 29th September the capacity of the coarse beds was as follows—

Description of bed.	Capacity of each bed in gallons.	Percentage of whole volume of bed.	Corresponding capacity per acre of bed.
Ragstone	200	40.0	544,500
Coke	250	50.0	680,625

The beds received one filling daily until January 11th, 1899, and then two fillings daily until the experiments were stopped. Before starting the two daily fillings the capacity of the beds was ascertained to be as follows—

Description of bed.	Capacity of each bed in gallons.	Percentage of whole volume of bed.	Corresponding capacity per acre of bed.
Ragstone	183	36.6	498,217
Coke	195	39.0	530,887

Two daily fillings would represent a million gallons per acre per day.

On January 20th, 1899, an attempt was made to estimate the free oxygen in solution in the effluents from the four beds, and the following results were obtained—

Ragstone, coarse bed	...	...	...	...	nil.
Coke	...	...	...	...	nil.
Ragstone, fine bed	...	...	...	...	18.0 per cent.
Coke	...	...	...	...	19.1 "

Complete saturation with oxygen was taken as 100.

The effluent obtained from the primary beds did not show as high a purification as had been expected; it is probable that the large size of the material had the effect of presenting an insufficient surface of contact with the sewage; the putrescible matter in the sewage was not therefore thoroughly dealt with by the bacteria.

On March 9th, 1899, the capacity of the beds was ascertained to be as follows—

Description of bed.	Capacity of each bed in gallons.	Percentage of whole volume of bed.	Corresponding capacity per acre of bed.
Ragstone	174	34.8	473,715
Coke	168	33.6	457,380

Table A (page 9) shows the varying capacities of these beds, and proves that the coke-beds became choked more quickly than the ragstone-beds.

During the first four months after starting the primary coke-bed it choked at the rate of 3·6 gallons per week, or 0·73 per cent. of the total capacity of the tank, and during the next two months the rate of choking was 3·4 gallons per week, or 0·68 per cent. of the total capacity of the tank. The ragstone-bed during the six months choked regularly at the rate of 1·1 gallons per week, or 0·22 per cent. of the total capacity of the tank.

Early in April, 1899, it was considered that the beds had reached their maximum power for purifying the sewage. They were then being filled twice a day, and were dealing with the sewage at the following rates—Ragstone, 947,430 gallons per acre per day; coke, 914,760 gallons per acre per day, and the average percentage purification effected during that month was—

Description of bed.	Percentage purification, as measured by oxygen absorbed from permanganate.	Percentage purification, as measured by albuminoid ammonia.
Ragstone, primary, coarse bed	17·5	32·6
Coke " " " " " " " " " " " "	16·5	21·3
Ragstone, secondary, fine bed	48·8	64·4
Coke " " " " " " " " " " " "	60·9	62·4

The amount of nitrification produced had fallen very low in the case of all the beds.

Abnormal amounts of nitrate were found in the first effluent from the ragstone fine bed after the bed had rested at Easter, from 29th March until 5th April, and it appeared probable that nitrates had been formed in the bed during the rest and had then been washed out by the first filling with sewage. A similar result was not found in any of the other beds.

The series of experiments with these beds terminated on the 15th April, 1899, after a period of 29 weeks' working. The average percentage purification effected during the last week was as follows—

Description of bed.	Percentage purification, as measured by oxygen absorbed from permanganate.	Percentage purification, as measured by albuminoid ammonia.
Ragstone, coarse bed	21·3	43·2
Coke " " " " " " " " " " " "	18·8	29·7
Ragstone, fine bed	50·7	66·5
Coke " " " " " " " " " " " "	58·5	68·6

The average percentage purification during the continuance of the experiments as measured by the oxygen absorbed from permanganate in four hours was as follows—

Ragstone coarse bed	20·6
Coke " " " " " " " " " " " "	22·5
Ragstone fine bed	49·1
Coke " " " " " " " " " " " "	63·2

The two coarse beds were thus shown to be doing very unsatisfactory work. It was hoped that an improved effect would be produced if a reduction were made in the size of the material in the bed. That this expectation was justified will be seen by the fact that the results obtained in the next series of experiments, when the primary beds were composed of coke fragments one-half to two inches in diameter, showed an average purification of 43·8 per cent.

With regard to the secondary treatment of the primary effluent with fine material, the results furnished by the ragstone did not at all come up to expectations, and were far less satisfactory than those obtained with the coke. The amount of nitrification produced by this bed was, however, much greater than that produced in the corresponding coke-bed. It has recently been shown that the presence of nitrates in an effluent may prevent the putrifaction of a certain amount of organic substances from occurring in another effluent with which the nitrate-effluent has been mixed; hence the nitrifying power of the ragstone beds is not without importance.

The beds were filled once a day from 22nd September, 1898, to 9th January, 1899, both inclusive. The filling was, however, not carried out on Sundays or on Christmas holidays, and occasionally one or two days were missed when the boiler was undergoing cleaning. In all, filling was carried on on 83 days out of the 110. During this period the ragstone-beds dealt with a total of 16,800 gallons, which was equivalent to 415,800 gallons per acre per day, including all resting periods; while the coke-beds dealt with one-fourth more than this quantity. From 11th January, 1899, to 15th April, 1899, when the experiment terminated, the beds were filled twice daily on 73 days out of the total of 95. During this period the ragstone-beds dealt with a total of 20,976 gallons, which is equivalent to 601,128 gallons per acre per day, while the coke-beds dealt with a total of 21,864 gallons, equivalent to 626,576 gallons per acre per day, all resting periods included. The total volume of sewage dealt with over the whole period of the experiment was therefore—

Ragstone beds	37,776 gallons.
Coke beds	42,864 " "

Expressed in terms of an acre these quantities would represent, on the days the beds were actually at work during the first period of the experiment with one filling per day, the following volumes—

Ragstone	...	...	...	551,060 gallons per acre per day.
Coke	...	...	...	688,825 " " "

and during the second period of the experiment, with two fillings per day—

Ragstone	...	...	...	782,290 gallons per acre per day.
Coke	...	...	...	815,407 " " "

The detailed results obtained by the chemical examination of the sewage and of the effluents are tabulated on pp. 17 to 19. The average purification, as measured by the oxygen absorbed from permanganate in four hours, during the whole continuance of the experiment was as follows—

Description of bed.	Oxygen absorbed from permanganate.	Percentage purification.
Ragstone, coarse bed	3.015	20.6
Coke " " " " "	2.944	22.5
Ragstone, fine bed	1.933	49.1
Coke " " " " "	1.396	63.2
Crude sewage, for comparison	3.797	

The average purification effected by one daily filling was—

Description of bed.	Oxygen absorbed.	Percentage purification.
Ragstone, coarse bed	3.003	20.2
Coke " " " " "	2.923	22.3
Ragstone, fine bed	2.002	46.8
Coke " " " " "	1.323	64.9
Crude sewage, for comparison	3.764	

The average purification effected during two fillings per day was—

Description of bed.	Oxygen absorbed.	Percentage purification.
Ragstone, coarse bed	3.028	21.0
Coke " " " " "	2.969	22.6
Ragstone, fine bed	1.855	51.6
Coke " " " " "	1.478	61.5
Crude sewage, for comparison	3.834	

It will thus be seen that coke gives better results than ragstone in the removal of organic matters in solution; the results are slightly better on the primary treatment, and considerably better on the secondary treatment. It will also be observed that, with the exception of the fine coke-bed, which showed a slight decline, two fillings a day gave a rather better result than was obtained with one filling per day, showing that although the purifying power of the beds, owing probably to the large size of the material, was in itself low and unsatisfactory, still the beds were not being overworked. It points to the conclusion that from 20 to 23 per cent. purification was all that could be obtained by a one-contact treatment of the unsedimented crude sewage dealt with in a bed composed of material of so large a size that it would pass a 4-inch mesh and be rejected by a $\frac{1}{2}$ -inch mesh.

Effect of the Effluents on Fish life—The effluents from the primary beds killed gold and silver fish in a few hours, but those from the secondary beds sustained fish life as readily as fresh tap-water does.

It should be stated that the raw sewage which was supplied to the beds was of the heaviest kind. It was drawn from a level about a foot from the bottom of the sewer, and passed through a $\frac{1}{2}$ -inch screen to the beds without any previous sedimentation.

Table A.—Variation in Percentage Capacity of the Primary Beds.

Ragstone 40	...	...	} Already called "original capacity."
Coke 50	...	...	
Ragstone 36.6	...	...	} After an interval of 15 weeks.
Coke 39	...	...	
Ragstone 34.8	...	...	} After a further interval of 8 weeks.
Coke 33.6	...	...	

The "original capacity" here shown was taken about 7 days after the experiments had been started; it is probably below the total capacity, since it was taken while the beds were being emptied, and the drainings of the beds were therefore not included. No doubt a more trustworthy method of estimating capacity consists in filling the bed after it has drained for a definite time, which should be the same in all processes of taking capacities. It might be well that a standard "drainage period" should be recognised generally, since the wetness of the bed-material must affect the so-called capacity considerably. Thus a bed which had been draining for one hour only would require less liquid to fill it than one which had been draining for ten hours. In the case of the one-acre bed at Barking it is known that the effluent will continue to drain away for several days.

2.—PRIMARY AND SECONDARY TREATMENT IN BEDS OF COKE 10 FEET IN DEPTH.

For the purpose of these experiments iron super-structures 4 feet in height were bolted to the existing tanks, and the joints were caulked and made watertight. Thus the depth of the tanks was increased to 10 feet. The tanks were then filled to a depth of 9 feet 9 inches with coke, and were worked in two series as follows—

Series A.—

- (1.) A primary coarse bed. (A.)
- (2.) A secondary coarse bed. (A 1.)

Series B.—

- (1.) A primary coarse bed. (B.)
- (2.) A secondary fine bed. (B 1.)

The three coarse beds were composed of coke of such a size that it would pass a 2-inch mesh and be rejected by a $\frac{1}{2}$ -inch mesh.

The fine bed was composed of coke of a size which would pass a $\frac{1}{2}$ -inch and be rejected by a $\frac{1}{16}$ -inch mesh. In this instance the coke which had been in use in the previous experiments, and was thus in good bacterial condition, was mixed with two-fifths of its bulk of new material in forming the deeper bed. The arrangement of the tanks allowed the effluent from the primary beds to drain completely into their respective secondary beds.

The sewage supplied to the beds was obtained from the same source as during the previous experiments, and was thus of the strongest nature, and contained sand and other suspended mineral and vegetable matters which should not be allowed to reach the bed, and which a short period of sedimentation would, in a very great measure, remove. It speaks well for the beds that they have been able to cope so satisfactorily with the heavy work which was thrown upon them.

In series B the depth of the primary coarse bed was reduced to 9 feet 6 inches, in order that its liquid contents should not overflow when it passed into the secondary fine bed, whose capacity was somewhat smaller, owing to its being made of finer material.

The procedure was precisely similar to that adopted in the previous experiment. The two primary beds were filled simultaneously, were allowed to rest full for two hours; they were then drained into the secondary beds, and the effluent was allowed to remain for a further period of two hours in contact with the coke. The crude sewage and each of the effluents were separately sampled and subjected to examination.

Percentage Capacities of the Beds—The beds were charged by means of a fixed syphon made of one-inch pipe from an overhead water-tank, which was kept constantly full. The volume delivered by this syphon per minute was ascertained, and the capacity was then determined by the length of time required for filling each bed.

The following figures indicate the capacity of the various beds expressed as percentages of the total tank volume.

1899.	Primary coarse bed A.	Secondary coarse bed A 1.	Primary coarse bed B.	Secondary fine bed B 1.
29th May—dry coke ...	68·7	61·7	70·3	53·1
20th September ...	41·9	56·8	33·3	48·1
27th October ...	32·3	54·9	32·7	46·9
6th December ...	31·3	53·1	27·6	48·1
4th January, 1900 ...	26·8	50·6	24·7	47·0
7th February...	21·8	50·6	21·2	44·4

The progressive decrease in the capacity of the beds shows that they were choking. This cannot be wondered at, considering that the very worst of the sewage was being dealt with, and that sand and other solid matter was being admitted to the beds. Latterly, trouble had been experienced in filling the primary beds, owing to the accumulated mass of undissolved matters on the upper part of the beds. The beds, however, were doing very satisfactory purifying work, and were removing from 40 to 50 per cent. of the dissolved putrescible matters.

It was noticed that after seven months' work the coarse bed B had sunk to the extent of 6 inches. On 20th February, 1900, 9 inches of new coke, similar to that originally used, was placed on the top of this bed, and the depth of the bed was thus brought up to 9 feet 9 inches, as in the case of the other three tanks, the capacity of the bed having fallen sufficiently to prevent its contents from overflowing the secondary fine bed.

The decrease in the capacity of the beds was as follows—

Periods of working each bed. .	Total loss in capacity in gallons.	Decrease in capacity per week	
		Stated in gallons.	Stated in percent- age of original capacity.
<i>Coarse bed A (primary)</i> —			
September 20 to October 27, 1899 (5 weeks) ...	84	16·8	1·92
October 27 to December 6, 1899 (6 weeks) ...	20	3·3	0·17
December 6 to January 4, 1900 (4 weeks) ...	44	11·0	1·12
January 4 to February 7, 1900 (5 weeks) ...	48	9·6	1·00
Average loss per week*		9·8	1·00
<i>Coarse bed B (primary)</i> —			
September 20 to October 27, 1899	5	1·0	0·12
October 27 to December 6, 1899	49	8·2	0·85
December 6 to January 4, 1900	38	9·5	0·72
January 4 to February 7, 1900	33	6·6	0·70
Average loss per week*		6·3	0·60
<i>Coarse bed A 1 (secondary)</i> —			
September 20 to October 27, 1899	18	3·6	0·38
October 27 to December 6, 1899	19	3·2	0·30
December 6 to January 4, 1900	24	6·0	0·62
January 4 to February 7, 1900	nil	nil	nil
Average loss per week*		3·2	0·31
<i>Fine bed B 1 (secondary)</i> —			
September 20 to October 27, 1899	12	2·4	0·24
October 27 to December 6, 1899	12	2·0	0·20
December 6 to January 4, 1900	11	2·7	0·27
January 4 to February 7, 1900	26	5·2	0·52
Average loss per week*		1·9	0·19

Although the apparent average loss of capacity was much greater in coarse bed A than in coarse bed B (both primary), the actual capacity of B was slightly smaller than that of A, being 21·2 per cent., as against 21·8 per cent. in A. This is accounted for by the fact that a much greater decrease in capacity occurred in bed B before the 20th September than in bed A after the 20th September.

Work was commenced on Tuesday, 4th July, 1899, the beds receiving one filling per day up to 15th July, when it was thought advisable to fill the beds only three times in the week.

From 21st September the beds received one filling a day, and from 11th December onward two fillings a day.

The purification as measured by the amount of oxygen absorbed from permanganate, effected up to the end of the year 1899 is stated in the following table, in which the numbers in the first column represent the average percentage purification effected during the period when the beds were filled three times a week, the second column the period of one filling a day, the third column the period of two fillings a day, and the last column the average percentage purification effected by each bed from the commencement of the experiment until 31st December, 1899.

Description of bed.	Three fillings a week.	Six fillings a week.	Twelve fillings a week.	Average.
Primary coarse bed A ...	43·9	45·3	45·0	43·9
Secondary coarse bed A 1 ...	62·3	63·6	61·1	62·5
Primary coarse bed B ...	43·5	45·3	43·9	43·8
Secondary fine bed B 1 ...	79·1	76·1	67·6	76·2

A further improvement is observable in the efficiency of the beds since December 31st last up to the date of writing (10th February, 1900), the average percentage purification effected during that period having been as follows—

Primary coarse bed A ...	46·4
Secondary coarse bed A 1 ...	64·2
Primary coarse bed B ...	47·3
Secondary fine bed B 1 ...	71·0

* This average is calculated from the total loss of capacity which took place during the 20 weeks of experiment.

Relative Temperatures of the Atmosphere and of the Sewage and Effluents.

In Table 2 (page 19) the detailed temperature readings of the atmosphere and the effluents during December, 1899, are given. From a general consideration of the averages of these readings it appears that when the atmosphere was at a temperature of 38.5° Fahr. the sewage flowed into the primary beds at a temperature of 53° Fahr.; and that after it had remained in the primary beds for two hours it flowed into the secondary beds at a temperature of 46° from bed A and of 44.5° from bed B, the air temperature at that time being 38.0° . After the sewage had remained in the secondary beds for two hours it was drawn off, and showed a temperature of 44° from bed A1, and 42.5° from bed B1, the air temperature at the time being 37.5° . It will be observed that the average temperature of the outside air fell during the whole process 1° Fahr., and that the sewage fell 7° while it remained for two hours in the primary bed A, and a further 2° while it remained another two hours in the secondary bed A 1, or 9 degrees out of a possible 15.5 degrees' fall during the whole process. In series B the sewage fell in temperature 8.5° after two hours' rest in the primary bed and a further 2° after another two hours in the secondary bed, or 10.5 degrees out of a possible fall of 15.5 degrees during the whole process.

In considering this question of temperatures the following facts must be borne in mind—(1) that the beds were small in area; (2) that their position was exposed, that they stood in metal tanks supported entirely above the ground level, and that each tank was widely separated from the others; and (3) that since the tanks were constructed of thin galvanised iron, their exteriors readily lost heat by radiation as well as by contact with the cold air.

The somewhat lower temperatures found in series B are explained by the fact that the latter is somewhat more exposed than series A, which stands between series B and a wooden wind-screen.

In another series of readings which are given in Table 3 (page 20) the air temperature fell 2.5° Fahr. during the process of treatment of the sewage—from 43.5° to 41° ; and the temperature of the sewage fell in both series of beds (A and B) 4.5° in its passage through the primary beds, and 1 degree more in passing through the secondary beds—a total fall of 5.5° out of a possible 9.5° . In series A the temperature of the beds themselves was taken about four hours after they had been emptied, and the average temperature of the primary bed was found to be equal to that of the sewage which had flowed into the bed, viz., 50.5° Fahr., while the outside air stood at 42° . The average temperature of the interior of the secondary bed was 48° , or 2° higher than that of the effluent from the primary bed with which it had been filled, and 3° above that of the effluent when it was drawn off four hours previous to the test, the outside air standing at 41° Fahr.

These details may be summarised as follows—The temperature of the liquid, while it was standing in the primary bed, fell 4.5 Fahr., but after the liquid had been drawn off, the bed recovered from this loss of temperature in four hours; this recovery could evidently only be effected by some internal action which was attended with the production of heat, and is probably due to the action of the bacteria upon the moist suspended matters contained in the bed. The liquid, in passing through the secondary bed, lost a further degree in temperature, but the bed, after standing empty for four hours, rose in temperature again to the extent of 3° Fahr.

Composition of the Air contained in the Body of the Primary Bed B.

Many analyses were made of the air contained in the empty coke-beds. The detailed results are given in Table 4 (pp. 20 and 21). From the 19th October to the end of 1899 the air present in the interstices of the coke-bed, after it had remained empty for the average time of twenty-one hours on several different occasions, contained the following average percentages of oxygen and carbon dioxide—

Oxygen	...	...	...	10.3
Carbon dioxide	...	...	...	5.7

Between January 1st and February 23rd, 1900, when the bed had remained empty on many occasions for an average period of five hours, the following average percentages were found in the interstitial air—

Oxygen	...	...	...	8.0
Carbon dioxide	...	...	...	5.7

Fresh air contains on an average the following percentages—

Oxygen	...	...	...	20.96
Carbon dioxide	...	...	...	0.04

The average proportion of oxygen present in the air at the bottom of the bed, as compared with that present in fresh air therefore was, up to the end of 1899, with the bed standing empty for twenty-one hours, about 50 per cent. From the commencement of the present year until 23rd February, with the bed standing empty for the average period of five hours, the aëration, as measured by the above proportion of oxygen, has been about 38 per cent. This is by no means so satisfactory a condition as could be desired, and is probably due to the fact that the bed had become clogged by the heavy suspended matters of the crude sewage, and that the putrifactive bacteria acting on these matters rapidly absorb oxygen from the air and liberate carbon dioxide and other gases.

Suitability of the Effluent to Maintain Fish life.—The effluent from the primary beds was capable of sustaining the life of gold fish apparently indefinitely. Less hardy fish, such as roach, dace, and perch, became sickly after living in the effluent for a week or two. It should be remarked, however, that the fish were in a somewhat sickly condition before they were placed in the effluent.

Nitrification.—The average amount of nitrification produced by the nitrifying organisms in the various beds up to 31st December, 1899, is indicated by the following numbers—

Description of liquid examined.	Weight of oxidised nitrogen present in the sewage and in the effluent in grains per gallon.	
	Nitrous nitrogen.	Nitric nitrogen.
Crude Sewage	0·0040	0·1602
Effluent from Primary coarse bed A	0·0932	0·4474
" " " " B	0·0645	0·3562
" Secondary coarse bed A 1	0·0767	0·9279
" Secondary fine bed B 1	0·0409	1·5861

It will be seen that the sewage arrived at the works containing an average amount of 0·1602 grains per gallon of nitric nitrogen, which shows that it was fairly fresh. It contained, as a rule, no nitrous nitrogen.

Comparing the amounts of oxidation of nitrogen produced in the various bed, the amount of nitrous oxidation effected in the primary beds was reduced by 17·7 per cent. in the secondary coarse bed and by 36·6 per cent. in the secondary fine bed. On the other hand the amount of nitric oxidation effected in the primary beds was increased by 107·4 per cent. in the secondary coarse bed and by 345·3 per cent. in the secondary fine bed.

3.—THE BACTERIAL TREATMENT OF THE SEDIMENTED CHEMICAL EFFLUENT IN THE ONE ACRE SIX-FEET COKE-BED.

The one-acre coke-bed, as it was originally laid down, consisted of three feet of unsifted pan breeze obtained from the adjacent Beckton Gas Works. In 1898 the depth was increased to 6 feet by placing on the top of the old bed 3 feet of coke, in pieces from half-an-inch to one inch in diameter and sifted free from dust. Its area was really 5,067 square yards instead of 4,840 square yards.

The bed was first filled on 29th April, 1898, in order to test the pipes for leakage, and it was observed that the surface of the bed settled down considerably in the central portion. The bed was re-levelled and work was re-commenced on the 12th May, 1898. On the following day the effluent from the bed showed a purification of 81·2 per cent. as compared with the chemical effluent, which was allowed to flow upon this bed. The bed was filled once a day until 2nd July, 1898, from after that date one filling per tide was dealt with: this amounted practically to two fillings a day. The bed had to be worked according to the tide, because high-water mark in the river, into which the effluent was discharged, was above the level of the outfall for the effluent.

Quantities of chemical effluent dealt with and capacity of the bed.

The bed was filled once a day between 12th May, 1898, and 2nd July, 1898, with the exception of Sundays, when the bed rested empty. During this period the bed was filled 43 times, and dealt with a total volume of 29,986,048 gallons, or an average of 697,350 gallons at each filling. As the total capacity of the space occupied by the bed is 273,618 cubic feet, or 1,710,112 gallons, the bed showed a liquid capacity of 40·8 per cent. of its whole volume. During the period under notice the capacity of the bed, as calculated from the averages of the first and last complete week's work, fell 71,045 gallons, this being equal to a decrease of 4·15 per cent. during the whole period, or to 0·59 per cent. per week.

During the week ending July 9th, 1898, the bed was dealing with sewage at the rate of 1,255,918 gallons a day for six days in the week, and resting on the seventh. This quantity is approximately equal to that dealt with by the old 3-foot bed when it was at its maximum working capacity and being filled three times a day.

As the effluent appeared to drain off very slowly from the bed, the engineer obtained the sanction of the Committee to construct a second outlet in order to hasten the process of emptying this bed. For this purpose the bed was thrown out of work on Friday, 29th July, 1898. The capacity of the bed at this time was 508,250 gallons, or 29·7 per cent. This is a fall of 12·2 per cent. from the average capacity during the week ending May 21st, 1898. The average capacity during this week was 717,503 gallons, and the last filling on the 29th July had shown 508,250 gallons.

The purification effected during the period from May 12th to 29th July, 1898, as shown by the oxygen consumed, averaged 79·7 per cent.

The regular filling of the bed was commenced again on 8th November, 1898. During the first two weeks after starting, the bed was filled once a day, but the work done was so efficient that tidal fillings were resumed on 21st November, and continued until 11th March, 1899, when the bed became foul and was thrown out of work. During this period (November 8th, 1898, to March 11th, 1899) the bed dealt with 98,743,447 gallons and effected an average purification of 84·3 per cent.

At the commencement of this period the capacity of the bed was 39·7 per cent.; at the end of the period it was 29·1 per cent. This is equal to a drop of 10·6 per cent. in seventeen weeks, or 0·6 per cent. per week.

The bed rested empty for eight weeks and was started again on 8th May, 1899. It was filled once a day during the first three days of this week, and rested empty until the Monday following in order to enable the engineer to carry out some experiments relative to the cost of

sifting the material composing the lower three feet of the bed. The bed was then filled once a day until the 30th May, when tidal fillings were again commenced.

Between the 8th May and 31st December, 1899, the bed was filled 361 times, and dealt with a total of 170,191,973 gallons, or with an average of 471,446 gallons per filling. This gives an average capacity of 27.6 per cent., or 1.5 per cent. lower than 11th March. The actual fall in capacity between the middle of May and the end of December, 1899, was 7.7 per cent. Since the end of the year 1899 the capacity has gradually diminished until it reached, on 3rd March, 1900, 21.8 per cent., and 20.1 per cent. on 21st April.

The purification effected during the period extending from the 8th May to 31st December, 1899, averaged 82 per cent., as measured by the removal of the dissolved oxidisable matters from the chemical effluent. The results of these examinations are given in Table 7 pp. 25 to 34.

On February 20th a hole was dug to the bottom of the bed after it had been draining for five or six hours, and it was found that liquid remained in the bed filling it to the surface of the old 3-feet bed. The water could be baled out, but the hole filled itself again by the liquid oozing very slowly through its sides from the surrounding parts of the bed. In other words the lower half of the bed remained permanently full of liquid. This was probably due to the consolidation of the unsifted fine pan breeze in the lower part of the bed by the weight of the upper layer of three feet; this upper part being coarse-sifted coke apparently remained open and unconsolidated. The liquid contents of the lower three feet of the bed were accordingly only forced through the drain-pipes during the process of emptying by the weight of liquid in the upper half of the bed, and as soon as the contents of the upper three feet reached the lower three feet of the bed they remained there while the bed was resting in air until they were forced out after the next filling. It appeared therefore that only the upper three feet of the bed was aerated by direct contact with the air when the effluent flowed out, and that the lower three feet of the bed must have obtained its oxygen from the liquid which had been in contact with the upper half of the bed. This condition of things probably explains the low nitrification which has always been found in effluents from this bed, as compared with those derived from other experimental beds in use on the works. It explains also the low liquid capacity of this bed. In all probability the liquid capacity was nearly double that which was shown by measuring the volume of the effluent discharged. The capacity measured was indeed that of the upper half of the bed only, the lower half remaining entirely filled with liquid.

III.—REPORT AS TO FURTHER EXPERIMENTS ON THE BACTERIAL TREATMENT OF CRUDE SEWAGE AT THE SOUTHERN OUTFALL (CROSSNESS).

1.—INTERMITTENT TREATMENT OF CRUDE SEWAGE BY SINGLE CONTACT IN A COKE-BED 13 FEET IN DEPTH.

A brick-lined tank, 22 feet 6 inches long by 10 feet 8 inches wide, and having a superficial area equal to $\frac{2}{3}$ of an acre, had already been filled with coke to a depth of 6 feet for the experiments which were described in the previous Report on the Crossness Experiments. The coke fragments were about the size of walnuts. This 6-foot bed had been acting as a secondary bed for about eight months, and had treated the effluent from a coke-bed fed with crude sewage for that period.

On February 27th, 1899, this bed was first filled with crude sewage, and its depth was increased by adding new coke fragments of similar size to the old, until on March 8th the bed was 12 feet deep. On April 11th another foot of coke was added giving the bed a total depth of 13 feet. This increase in depth was made in order to ascertain whether an increase in the depth of the bed in any way detracted from its efficiency. It will be evident that the capacity of a bed per unit of superficial area is increased in proportion to this increase in its depth.

In charging this bed crude sewage was pumped by a special engine and pump direct from the suction culvert of the main pumping engines of the Outfall, and was distributed from a trough over the surface of the bed. The liquid sank readily into the body of the coke-bed.

As soon as the bed was filled and the liquid appeared at the surface of the bed, the pumping was stopped. The sewage was then allowed to remain in contact with the coke for three hours, after which it was allowed to flow away slowly from the bottom of the bed.

The filling took from 20 to 25 minutes, and the draining away of the effluent from an hour to an hour and a half.

From February 27th to March 25th inclusive, the bed was filled once daily with sewage, and after March 27th it was generally filled twice daily.

The bed was charged once only on Saturdays and remained empty on Sundays and on holidays. The other rests were due either to accidents occurring to the driving belt or to the pump, or to the necessity arising for making alterations in the arrangements or for making capacity determinations of the bed.

The coke which was used in this bed occupied, while it was new, 49 per cent. of the whole volume of the bed, and the interstitial air or liquid occupied 51 per cent. This liquid space was reduced by June 8th to about 34 per cent., and by October 10th to about 28 per cent. This loss in capacity was equal to about 63 gallons decrease of liquid capacity per week, and threatened speedily to put an end to the work of the bed. In order to prevent further loss of liquid capacity the coarser suspended matter of the crude sewage was allowed to subside before the sewage flowed upon the bed.

With this object a large wooden tank was placed upon the top of the coke-bed, and the crude sewage was pumped into this and was allowed to overflow upon the bed.

The solid matter left behind in the tank consisted mainly of particles of sand, woody fibre, straw, paper and hair. It was generally of the same character as the matter which had been found adhering to the coke and which had been choking the bed. The result of this rough settlement was that by January 12th, 1900, the liquid capacity had increased from 28 per cent. to about 33 per cent.

The purification effected by this bed, as judged by the removal of dissolved organic matter was practically equal to that obtained by the 4-foot bed.

There is no reason why a deep bed should not give as good results as a shallow bed, provided that it is as well aerated during the periods when it is empty. Experiments have been already reported which proved that even the bottom of the 13-foot bed was well supplied with oxygen.

The effluent from this deep coke-bed has been usually slightly turbid; it possessed only a faint earthy smell, and it was capable of supporting fish life.

During the period under notice, from February 27th, 1899, to December 22nd, 1899, the bed had been filled 338 times.

Taking the average sewage capacity of the bed as being equal to 6,000 gallons, the quantity of sewage dealt with per acre per day would be, for one filling, 1,089,000 gallons; for two fillings, 2,178,000 gallons; and for three fillings, 3,267,000 gallons.

Experiments are now in progress which will prove whether this bed is capable of treating sewage satisfactorily at the rate of four fillings a day, the sewage supplied to it having undergone a short process of preliminary sedimentation.

2.—EXPERIMENT ON THE BACTERIAL TREATMENT OF RAPIDLY SEDIMENTED CRUDE SEWAGE.

For three weeks at the end of last year the crude sewage arriving at the Southern Outfall was not mixed with chemicals, and was allowed to flow through one of the large settling channels at an average rate of 7·4 feet per minute, the usual rate of flow of chemically-treated sewage being about 1·5 feet per minute. A portion of this sedimented sewage was then treated in a small coke-bed in the intermittent manner already described, the bed being filled thrice daily. Details of the results obtained are given on page 38.

An average percentage purification from dissolved oxidisable matter was obtained, amounting to 53 per cent., calculated on the sedimented sewage; this purification amounted to 58·7 per cent., if calculated on the crude sewage. The capacity of the bed was not reduced during the period of treatment.

3.—APPENDED REPORT ON THE 13-FOOT COKE BED. FEEDING WITH SEDIMENTED SEWAGE, AND INCREASED NUMBER OF FILLINGS PER TWENTY-FOUR HOURS. JANUARY 15TH TO JULY 28TH, 1900.

Continuing the history of this bed from the end of the last statement, the bed was not filled from December 22nd, 1899, to January 15th, 1900, owing to the experiments with the whole of the Crossness sewage being carried on at the same time.

From January 15th to April 5th, 1900, the bed was filled intermittently in the way already described, the sewage overflowing from a large wooden tank placed on the bed so as to allow the heavier and coarser suspended solids to settle out. The number of fillings per day is shown in the table which follows this statement.

On April 5th the bed had been filled with crude sewage three times daily for nearly 7 weeks. The coke was then seriously clogged upon the surface, and although the degree of purification effected was fully maintained, the bed had to be stopped in order to give time for the collection of matter in the upper part to become removed by bacterial action. The bed was allowed to stand in air from April 5th to May 2nd, 1900.

In the meantime, arrangements had been made to subject the sewage to a short, but more efficient, process of sedimentation in a brick tank of approximately 8,000 gallons capacity before it passed into the bed. The settled liquid was drawn off from near the surface of this tank, and as soon as the coke-bed had been filled the residual liquid remained at rest in the settling tank until it was again filled up with the crude sewage. Probably most of the liquid which passed into the coke-bed was therefore settled stale sewage, which was displaced by the incoming sewage. Some anaërobic (septic) bacterial action undoubtedly took place in this settling tank, and there was a considerable evolution of inflammable gas, but the extent by which the sludge was reduced in amount by this action could not be ascertained. The conditions of working would not allow of sufficiently accurate measurements of the incoming sludge being made, and an intermittent septic process of the above kind could hardly be suitable for dealing with the sewage of London.

Since May 2nd, the coke-bed has been filled intermittently from the brick settling tank three and four times daily; no clogging of the upper parts of the coke has been noticed, and the liquid sinks readily into the coke-bed as soon as it is allowed to pass upon the surface. The liquid capacity of the coke-bed was taken at long intervals, and has been found to be as follows—

January 12th—6,000 gallons.

June 16th—6,000 gallons.

October 8th—6,290 gallons (calculated from a determination of the capacity of half the bed).

The sludge deposited during eight weeks in the settling tank contained on the average 35 per cent. of organic matter.

NUMBER OF FILLINGS PER WEEK OF THE 13-FOOT COKE BED, AND WEEKLY
AVERAGE PURIFICATION.

Week ending	No. of fillings per week.	Average percentage purification as measured by the oxygen absorbed from permanganate in four hours.	
		By the total putrescible matter.	By the dissolved putrescible matter.
1900.			
January 20th	6	50.6	48.8
" 27th	6	58.0	62.0
February 3rd	6	56.0	58.0
" 10th	6	60.0	58.0
" 17th	2	51.0	45.0
" 24th	16	48.0	48.0
March 3rd	15	45.5	43.5
" 10th	15	53.0	51.0
" 17th	14	56.0	54.0
" 24th	16	52.6	52.1
" 31st	13	51.1	50.5
April 5th	9	49.0	51.0
" 5th to May 2nd, rest for choking, alterations, &c.	—	—	—
May 5th	6	46.0	54.0
" 12th	11	44.0	51.0
" 19th	11	56.0	57.0
" 26th	16	56.0	58.0
June 2nd	15	61.0	62.0
" 9th	17	53.0	52.0
" 16th	17	53.6	52.1
" 23rd	20	58.0	54.0
" 30th	21	55.0	47.0
July 7th	21	53.0	53.0
" 14th	20	61.0	58.0
" 21st	9	68.0	61.0
" 28th	11	65.0	60.0
Total	319	Average 54.4	53.6

4.—LIQUID CAPACITY OF A COKE-BED, AS IT IS AFFECTED BY THE SIZE OF THE
COKE FRAGMENTS.

The question has been raised as to the actual liquid capacity of one and the same tank according as it is filled with coke fragments of different sizes. It has been maintained that the liquid capacity of the interstices between the coke-fragments does not vary when the tank is successively filled with fragments of different dimensions, provided that in the case of each filling with coke the fragments are approximately of similar dimensions.

In order to test this a tank with a total capacity of 280 gallons was filled with small fragments of coke which passed a half-inch mesh, and subsequently with fragments about the size of the fist. In both cases the coke was allowed to soak in water until it was saturated, as was shown by the liquid capacity of the coke-tank becoming uniform when it was tested at intervals of several days. The period of soaking required was about four days. The liquid capacity was distinctly greater when the tank was filled with the large coke fragments than when it was filled with the small fragments. The relative capacities were as follows—

Capacity of small-coke bed	...	...	...	...	135 gallons.
" large-coke bed	...	...	...	...	150 gallons.

Further experiments seemed to show that this difference in capacity increased as the particles departed more widely from the spherical form. With truly spherical particles of uniform size, the difference of capacity arising from difference in the size of the particles entirely disappeared.

IV.—TABULATION OF THE RESULTS OF THE CHEMICAL EXAMINATION OF THE BACTERIALLY-TREATED CRUDE SEWAGE AND EFFLUENTS.

I.—BARKING RESULTS.

TABLE 1.—CHEMICAL RESULTS OF THE ESTIMATION OF THE AMOUNT OF OXYGEN ABSORBED FROM
PERMANGANATE BY THE SEWAGE AND BY THE EFFLUENTS FROM THE BEDS OF RAGSTONE AND COKE.

Date.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of—				
		Crude sewage.	Effluent from the Ragstone series.		Effluent from the Coke series.	
			Primary coarse bed.	Secondary fine bed.	Primary coarse bed.	Secondary fine bed.
1898.						
Sept. 22	Once	4.412	4.759	5.000	4.759	1.471
23	"	lost	4.510	4.412	4.608	0.784
26	"	2.059	3.039	2.353	2.353	0.882
27	"	2.330	2.718	2.524	2.718	0.777
28	"	1.942	2.039	1.748	1.845	0.582
29	"	2.600	2.500	1.900	2.700	0.600
30	"	3.300	3.200	2.500	3.200	0.900
Oct. 3	"	1.900	2.500	1.900	1.800	0.600
4	"	2.200	2.300	1.800	1.900	0.600
5	"	2.300	2.800	1.900	2.100	0.500
6	"	1.800	1.800	1.400	1.400	0.600
7	"	1.800	1.800	1.400	1.400	0.700
8	"	2.200	2.300	2.000	1.700	0.700
10	"	1.500	1.500	1.800	1.700	0.900
11	"	3.000	2.800	1.900	2.600	1.100
12	"	2.000	1.900	1.600	1.800	0.800
13	"	1.700	1.600	1.300	1.500	0.700
14	"	1.800	1.700	1.200	1.700	0.700
15	"	2.700	2.600	2.000	2.500	1.100
17	"	1.400	1.500	1.300	1.400	0.800
18	"	2.200	1.800	1.600	1.800	0.900
19	"	1.881	1.980	1.881	1.881	1.089
21	"	3.267	3.168	1.782	3.168	1.188
22	"	2.178	1.683	1.386	1.980	0.792
24	"	2.673	2.376	1.584	2.178	0.891
25	"	2.475	1.881	1.584	2.079	1.089
26	"	3.069	2.376	1.485	2.178	0.792
27	"	3.564	2.970	1.881	2.772	1.188
28	"	4.059	3.366	2.277	3.069	1.584
29	"	2.475	2.277	1.584	2.178	0.990
Nov. 2	"	4.158	3.168	2.277	3.366	1.386
3	"	4.059	3.366	1.782	3.069	1.287
4	"	3.564	2.772	1.485	2.574	1.584
5	"	4.275	3.366	2.277	3.267	1.287
7	"	3.366	2.970	1.782	3.267	1.386
8	"	3.960	3.168	1.881	3.168	1.287
9	"	3.663	3.267	1.980	3.069	1.881
10	"	3.564	2.970	1.980	2.871	1.584
11	"	3.663	3.162	1.782	3.069	1.386
12	"	4.356	3.465	2.376	3.366	2.079
14	"	3.069	2.871	1.881	2.673	1.287
15	"	4.554	3.069	1.980	2.673	1.485
16	"	4.158	2.970	1.386	2.673	1.683
17	"	4.158	3.168	1.782	3.267	1.368
18	"	4.554	3.069	1.881	3.069	1.980
19	"	4.653	3.564	1.980	3.366	2.079
21	"	4.000	3.500	2.000	3.300	1.400
22	"	4.000	3.400	1.800	3.600	1.400
23	"	4.800	3.600	2.000	3.500	1.600
24	"	4.700	3.900	2.300	3.900	1.700
25	"	4.800	3.500	2.100	4.000	1.500
26	"	4.400	3.000	1.500	3.200	1.100
28	"	4.100	3.000	1.900	3.000	1.500
29	"	4.300	3.400	1.800	3.900	1.400
30	"	6.000	3.500	2.500	3.600	1.900
Dec. 1	"	4.300	3.400	2.800	3.500	2.100
2	"	5.500	3.800	2.300	4.100	1.900

TABLE I.—(continued).

Date.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of—				
		Crude sewage.	Effluent from the Ragstone series.		Effluent from the Coke series.	
			Primary coarse bed.	Secondary fine bed.	Primary coarse bed.	Secondary fine bed.
1898.						
Dec. 3	Once	5·400	3·200	2·500	3·500	1·900
5	"	5·400	3·500	2·300	3·800	2·000
6	"	4·800	3·500	1·800	3·800	1·500
7	"	4·900	3·500	2·400	3·600	2·200
8	"	3·000	2·000	1·500	2·500	1·100
9	"	4·200	3·000	1·700	2·700	1·300
10	"	4·400	3·200	2·000	2·700	lost.
14	"	5·200	3·300	2·300	3·900	1·600
15	"	5·000	3·100	2·200	2·700	1·600
16	"	5·100	3·900	2·600	3·800	1·900
17	"	5·000	3·100	1·700	3·000	1·600
20	"	4·500	3·800	2·200	3·800	1·600
21	"	5·100	4·000	2·200	3·500	1·500
22	"	4·200	3·700	2·300	2·100	1·600
23	"	4·600	3·200	2·400	3·100	1·900
24	"	5·600	4·100	2·100	4·000	1·600
29	"	4·400	3·000	1·800	3·200	1·300
30	"	4·700	3·200	2·000	3·700	1·300
31	"	5·500	3·500	2·300	3·500	1·400
1899.						
Jan. 2	"	3·600	2·600	1·300	2·100	1·700
3	"	4·802	3·627	2·353	3·725	1·569
4	"	5·098	3·922	2·157	3·922	1·471
5	"	4·800	3·300	2·000	3·300	1·600
6	"	4·700	3·300	1·700	3·000	1·400
7	"	5·100	3·200	1·800	3·500	1·600
9	"	4·100	3·400	2·100	2·800	1·400
11	Twice	4·200	3·700	2·000	4·100	2·100
12	"	3·100	2·700	1·700	3·000	1·200
13	"	3·300	2·600	1·800	2·800	1·000
14	"	2·500	2·000	1·500	2·000	1·000
16	"	2·900	2·200	1·000	2·400	1·000
17	"	3·000	2·400	1·400	2·500	1·900
18	"	3·500	3·000	1·700	3·000	1·100
19	"	3·100	2·800	1·700	2·500	1·200
20	"	4·200	3·400	2·200	2·900	1·100
21	"	2·600	2·300	1·600	2·200	1·300
25	"	4·158	3·366	1·980	3·168	1·485
26	"	4·100	3·200	2·000	2·800	1·500
27	"	3·700	3·200	1·700	3·000	1·500
28	"	3·500	2·700	1·700	1·600	1·300
30	"	3·500	3·100	1·900	2·700	1·400
31	"	4·400	3·300	1·800	3·300	1·400
Feb. 1	"	4·200	3·400	2·200	3·300	1·600
2	"	4·000	2·700	2·600	3·300	1·500
3	"	4·000	3·400	1·900	3·500	1·400
4	"	3·000	2·700	1·800	2·500	1·400
6	"	3·400	2·800	1·600	2·600	2·100
7	"	2·900	2·300	1·500	2·200	1·300
8	"	3·100	2·500	1·500	2·400	1·200
9	"	3·100	2·600	1·500	2·300	1·200
10	"	3·300	2·400	1·400	2·100	1·300
11	"	3·500	3·300	1·600	3·100	1·400
13	"	2·700	2·000	1·700	2·200	1·300
14	"	3·000	2·600	1·800	2·300	1·500
15	"	4·000	3·000	1·900	3·100	1·500
16	"	3·200	2·700	1·700	2·700	1·500
17	"	3·700	2·900	1·600	2·900	1·300
18	"	3·300	2·500	1·700	2·600	1·300
20	"	3·400	3·000	1·700	3·100	1·300
21	"	3·900	3·000	1·700	3·100	1·500
22	"	4·400	3·000	2·000	3·000	1·500
23	"	4·400	3·500	1·900	3·300	1·600
24	"	4·700	3·600	2·100	3·700	1·700
25	"	3·700	3·400	2·000	3·000	1·700
27	"	3·700	3·000	1·700	3·000	1·500
28	"	4·600	3·100	1·900	3·100	1·500
Mar. 1	"	4·300	2·900	1·800	2·800	1·300
4	"	3·500	2·600	1·900	2·900	1·500

TABLE I.—(continued).

Date.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of—				
		Crude sewage.	Effluent from the Ragstone series.		Effluent from the Coke series.	
			Primary coarse bed.	Secondary fine bed.	Primary coarse bed.	Secondary fine bed.
1898.						
Mar. 6	Twice	4·000	2·900	1·800	3·000	1·500
7	"	4·300	3·100	1·900	2·900	1·400
8	"	4·500	3·300	2·000	3·100	1·500
9	"	5·100	3·800	2·200	3·900	1·700
10	"	4·700	3·400	2·100	3·300	1·900
11	"	3·800	3·000	1·900	3·100	1·600
13	"	4·216	3·725	1·863	3·627	1·863
14	"	4·412	3·627	2·157	3·529	1·863
15	"	4·216	3·137	2·255	2·941	1·863
16	"	4·706	3·431	2·255	3·235	1·667
17	"	4·314	3·235	2·059	3·333	1·863
18	"	3·725	2·950	2·059	2·745	1·373
20	"	4·314	3·333	1·863	3·333	1·569
21	"	4·623	3·585	1·981	3·396	1·698
22	"	4·623	3·208	2·264	3·113	1·981
23	"	4·057	2·925	1·604	2·736	1·415
24	"	4·434	2·925	1·887	3·019	1·604
25	"	4·057	3·396	2·170	3·775	1·604
27	"	4·623	3·679	2·075	3·775	1·604
28	"	4·528	3·491	2·170	2·830	1·698
29	"	5·189	3·775	1·698	3·302	1·887
Apl. 5	"	5·094	4·717	2·736	5·000	1·792
6	"	4·057	3·208	2·547	3·208	1·509
7	"	3·868	3·396	2·075	3·019	1·321
8	"	4·151	3·585	1·792	3·585	1·604
10	"	2·925	2·264	1·415	2·547	1·321
11	"	3·208	2·359	1·604	2·736	1·321
12	"	4·057	3·019	1·887	2·736	1·509
13	"	3·775	3·019	1·698	2·925	1·415
14	"	2·736	2·170	1·415	2·359	1·321
15	"	2·830	2·547	1·604	2·547	1·226
Averages		3·797	3·015	1·933	2·944	1·396

TABLE 2.—TEMPERATURE READINGS OF THE ATMOSPHERE AND OF THE EFFLUENTS FROM THE COKE-BEDS OF SERIES A. AND B.

Temperatures in degrees Fahrenheit.

Date.	Air.	Crude sewage.	Air.	Effluent from primary bed A.	Effluent from primary bed B.	Air.	Effluent from secondary bed A l.	Effluent from secondary bed B l.
1899.								
Dec. 11	33·0	53·0	30·5	48·0	43·0	29·0	40·0	38·0
12	34·0	54·5	34·0	42·0	40·5	32·0	40·0	39·5
12	33·5	55·0	36·0	47·0	42·0	36·0	43·0	40·0
13	32·0	54·0	32·0	42·0	40·0	30·0	42·5	41·0
14	32·0	54·5	36·5	45·5	42·0	34·0	42·5	39·5
15	35·0	54·0	35·0	44·0	42·0	30·5	43·5	39·0
15	32·0	55·0	30·5	45·0	45·5	32·0	42·5	40·5
16	32·0	55·0	32·0	41·0	40·0	30·0	42·5	41·0
16	44·0	52·0	35·0	43·0	41·5	35·0	43·0	41·5
18	43·0	54·0	40·0	44·0	44·0	41·0	42·0	41·0
19	42·0	53·0	41·0	45·0	45·0	35·0	44·0	44·0
20	40·0	53·0	40·0	47·0	46·0	39·0	45·0	44·0
21	41·0	54·0	39·0	47·0	46·0	40·0	44·0	45·0
27	34·5	53·5	33·0	44·5	41·5	34·5	41·5	40·0
28	30·0	53·0	34·0	44·0	42·0	36·0	39·0	38·0
28	43·0	52·0	43·5	46·0	45·5	46·0	43·5	43·0
29	47·0	50·0	47·0	50·0	49·0	51·0	46·0	46·0
29	52·5	48·0	50·0	51·0	51·5	49·0	51·0	51·0
30	46·0	53·0	46·5	52·0	52·0	47·5	50·0	50·0
30	45·0	53·0	44·0	51·0	51·0	45·0	51·0	50·5
Averages	38·5	53·0	38·0	46·0	44·5	37·5	44·0	42·5

TABLE 3.—TEMPERATURE READINGS OF THE ATMOSPHERE, OF THE CRUDE SEWAGE, OF THE EFFLUENTS FROM THE COKE-BEDS AND OF THE INTERIOR OF THE COKE-BEDS OF SERIES A. AND B.

Temperatures in degrees Fahrenheit.

Date.	Air.	Crude sewage.	Air.	Primary beds.			Air.	Secondary beds.		
				Interior of bed A.	Effluent from bed A.	Effluent from bed B.		Interior of bed A 1.	Effluent from bed A 1.	Effluent from bed B 1.
1900										
Jan. 22...	51·0	49·0	52·5	53·5	57·0	57·0	53·5	50·0	53·5	54·5
23...	53·5	52·5	52·0	54·5	52·5	52·0	52·5	52·0	52·5	52·0
24...	52·0	53·5	50·0	59·0	52·5	53·5	50·0	59·0	52·0	52·0
24...	57·0	53·5	52·5	57·0	54·5	53·5	47·5	53·5	52·0	50·0
25...	53·5	48·0	53·5	53·5	50·0	51·0	44·5	53·5	50·0	48·0
25...	57·0	52·0	49·0	57·0	52·0	52·0	50·0	55·0	52·0	52·5
26...	49·0	53·5	48·0	52·5	52·0	51·0	48·0	59·0	52·0	50·0
26...	52·0	53·5	52·5	53·5	53·5	52·5	49·0	55·5	51·0	51·0
27...	53·5	53·5	52·5	54·5	51·0	51·0	39·0	52·5	50·0	50·0
29...	41·0	50·0	48·0	50·0	52·0	51·0	48·0	50·0	52·0	52·0
30...	46·5	51·0	48·0	46·5	47·5	46·5	37·5	46·5	43·0	43·0
30...	41·0	51·0	30·0	50·0	44·5	44·5	39·0	41·0	43·0	43·0
31...	40·0	48·0	43·0	41·0	44·5	43·0	48·0	42·0	47·0	46·5
31...	43·0	52·0	43·0	53·5	44·5	44·5	42·0	53·5	44·0	44·5
Feb. 1...	44·5	51·0	37·5	48·0	40·0	41·0	34·0	37·5	41·0	41·0
1...	37·5	51·0	37·5	52·0	42·0	42·0	38·0	50·0	43·0	43·0
2...	34·0	50·0	35·5	48·0	44·5	46·0	34·0	39·0	41·0	41·0
2...	35·5	50·0	36·5	51·0	41·0	41·0	34·5	50·0	42·0	42·0
5...	46·5	50·0	44·5	48·0	40·0	41·0	37·5	48·0	40·0	39·0
6...	37·5	48·0	35·5	50·0	41·0	41·0	35·5	48·0	39·0	40·0
6...	40·0	48·0	36·5	47·0	44·5	44·5	34·0	41·0	40·0	40·0
8...	30·0	50·0	28·5	47·0	39·0	39·0	25·0	43·0	37·5	39·0
8...	36·5	48·0	34·0	48·0	40·0	40·0	35·5	37·5	37·5	36·5
9...	36·5	48·0	34·5	48·0	41·0	39·0	34·5	36·5	39·0	37·5
10...	26·5	50·0	26·5	47·0	39·0	39·0	37·5	45·5	39·0	38·0
10...	37·5	48·0	36·5	48·0	41·0	39·0	35·5	44·5	41·0	39·0
Averages	43·5	50·5	42·0	50·5	46·0	46·0	41·0	48·0	45·0	45·0

TABLE 4.—PERCENTAGE COMPOSITION OF THE AIR AT THE BOTTOM OF THE PRIMARY COKE-BED B.

Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.	Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.
1899.				1899.			
Oct. 19	22	1·6	17·4	Nov. 17	17	8·0	10·5
20	20	3·0	15·6	20	68	2·0	16·4
23	19	4·2	14·8	21	17	4·0	15·0
24	19	8·8	4·0	22	17	6·0	12·4
25	19	11·4	1·4	23	19	8·0	12·1
28	43	8·0	6·4	24	19	7·6	12·2
31	19	4·0	9·0	28	19	8·6	6·0
Nov. 1	19	5·0	7·4	29	19	7·6	6·4
2	20	4·0	10·0	Dec. 1	19	8·8	3·2
3	20	3·6	9·8	5	19	7·5	6·1
4	38	3·6	10·2	7	19	8·8	3·0
6	19	7·0	8·2	8	19	4·0	13·0
7	19	8·6	4·2	12	19	5·8	11·8
9	19	4·0	16·0	13	19	5·0	11·8
10	16 $\frac{1}{2}$	5·0	13·6	14	19	7·2	10·2
13	67	1·2	18·2	19	4	6·0	5·0
14	17	3·0	15·0	20	4	7·0	5·0
15	17	3·6	15·2	21	4	8·0	4·2
16	17	4·0	15·6	22	4	2·4	13·6
Averages	21	5·7	10·3				

In pure atmospheric air the average percentage of carbon dioxide is 0·04, and of oxygen 20·96.

TABLE 4.—(continued).

Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.	Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.
1900. Jan. 2	4	7·8	5·8	1900. Jan. 23	4	5·4	9·4
3	4	9·9	3·9	25	4	6·4	6·4
4	4	1·8	17·2	26	4	5·2	10·8
9	4	7·0	9·8	30	4	4·6	5·4
10	4	6·9	7·7	Feb. 1	4	3·6	10·4
11	4	7·8	3·6	2	4	3·4	9·8
12	4	5·6	8·4	6	4	5·4	8·2
16	4	6·0	4·9	8	4	7·0	8·0
17	4	4·7	7·9	9	4	4·0	9·8
18	4	2·8	11·2	22	4	6·4	8·0
19	24	6·6	3·4	23	4	7·8	5·6
Averages				5 5·7 8·0			

In pure atmospheric air the average percentage of carbon dioxide is 0·04, and of oxygen 20·96.

TABLE 5.—AMOUNT OF NITRIFICATION PRODUCED IN THE COKE BEDS OF SERIES A AND B.

Date.	Nitrogen as Nitrite in					Nitrogen as Nitrate in				
	Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.		Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.	
		Primary Coarse Bed.	Secondary Coarse Bed.	Primary Coarse Bed.	Secondary Fine Bed.		Primary Coarse Bed.	Secondary Coarse Bed.	Primary Coarse Bed.	Secondary Fine Bed.
1899. July 4	Nil	Nil	Nil	Nil	0·1400	0·1306	0·1325	0·1306	0·1625	0·3387
5	"	"	"	"	0·1750	0·0618	0·0850	0·0556	0·0368	1·1900
6	"	"	"	"	0·2450	0·0837	0·2281	0·0975	0·2206	0·8625
7	"	"	"	"	0·2450	0·1162	0·1012	0·0587	0·0381	0·9818
8	Slight trace	"	"	"	0·2800	0·1437	0·0662	0·1075	0·1056	0·2587
11	Nil	"	"	"	0·2520	0·0612	0·0506	0·0719	0·1106	1·7305
12	"	"	"	"	0·1610	0·1925	0·0762	0·2125	0·1350	1·1915
13	"	"	"	"	0·0280	0·1306	0·1987	0·1468	0·1481	1·9176
14	"	"	"	"	0·0308	0·1356	0·1662	0·1218	0·1450	2·2761
15	"	"	"	"	0·1050	0·0837	0·1444	0·2687	0·1906	1·6294
17	"	"	"	"	0·0140	0·1112	0·2232	0·0319	0·0969	2·0956
19	"	"	0·1190	"	0·0250	0·0275	0·0294	Nil	0·1181	1·9387
21	"	0·0280	Nil	"	0·0210	Trace	0·1032	Trace	0·0362	1·6415
24	"	0·1050	0·4480	"	0·0393	0·1207	0·1970	0·1980	0·1206	1·2217
26	"	0·0140	0·3150	"	0·0336	0·1530	0·1240	0·1670	0·1789	1·2284
28	"	Nil	0·2100	"	0·0420	0·1181	0·4385	0·4087	0·1856	1·1950
31	"	0·0182	0·2100	"	0·0532	0·1201	0·4528	0·4781	0·1800	0·0668
Aug. 2	"	0·0210	0·2100	"	0·0420	0·0856	0·0979	0·3762	0·1775	1·2640
4	"	Nil	0·2100	"	0·0140	0·0468	0·0701	0·3881	0·0726	1·4300
9	"	0·3780	0·0420	0·2100	0·0210	0·0357	0·5166	1·1650	0·0910	1·7470
11	"	0·2800	0·0560	Nil	0·0350	0·2410	0·2001	0·9195	0·4770	2·3400
14	"	0·2800	0·0560	"	0·0350	0·1493	0·2600	0·8460	0·1756	1·9540
16	"	0·2800	0·0700	"	0·0420	0·2947	0·0395	1·7570	0·2365	1·8700
18	"	0·1400	0·0600	"	0·0280	0·2370	0·4627	1·6370	0·2425	1·6690
21	"	0·0560	0·0420	"	0·0280	0·1815	0·1822	1·1660	0·1815	1·3160
23	"	0·0140	0·1400	"	0·0140	0·2426	0·0548	1·8806	0·2415	1·8400
25	"	0·0140	0·1400	"	0·0350	0·3566	0·3413	1·0840	0·3623	1·8650
28	"	0·1736	0·0582	0·2100	0·0210	0·0618	0·9054	1·1828	1·1050	2·4650
30	"	0·3500	0·1050	0·2800	Nil	0·4818	1·0970	1·5950	0·2000	1·8120
Sept. 1	"	0·2800	0·0350	0·0252	"	0·1703	0·5665	0·1986	2·0760	0·8441
4	"	0·2100	0·0420	0·0210	"	0·1156	1·7780	2·4400	0·4748	1·6160
6	"	0·2800	0·1050	Nil	0·0280	0·1818	0·9230	1·5230	0·1794	1·7150
8	"	0·0210	0·1400	"	0·0420	0·3578	0·4000	1·8620	0·3586	1·8350
11	"	0·2800	0·1400	0·2100	0·0210	0·0981	0·1968	0·7500	0·2760	0·5852
13	"	0·2800	0·0280	0·2100	0·0140	0·0903	0·4498	1·9425	0·1105	2·3566
15	"	0·0840	0·0490	0·0140	0·0350	0·1325	0·5956	1·2853	0·3375	2·6590
18	"	0·0252	0·0840	0·0420	0·0280	0·1161	0·5621	1·3990	1·1670	1·9730
21	"	0·2100	0·0280	0·0210	0·0280	0·2336	0·3773	0·7260	0·0560	0·7420
22	"	0·2800	0·0560	0·3500	0·0420	0·1580	0·7003	1·0400	0·6510	1·6660
23	"	0·0140	0·2100	0·0140	0·0128	0·1903	0·2214	0·6418	0·3952	1·5672
25	"	0·0210	0·2100	0·0182	0·0280	0·2351	0·6871	0·7911	0·7524	2·0630
26	"	0·0140	0·0420	0·0140	0·0210	0·1480	0·2977	0·9201	0·5899	1·4400
27	"	0·0210	0·1400	0·0210	0·0280	0·3623	0·6965	0·9431	0·4631	1·6526
28	"	0·0210	0·0280	0·0182	0·0252	0·2545	1·0738	1·2991	0·6953	0·8778
29	"	0·0210	0·0420	0·0210	0·0182	0·2953	1·1630	1·2600	0·5673	1·4048

TABLE 5.—(continued).

Date.	Nitrogen as Nitrite in					Nitrogen as Nitrate in				
	Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.		Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.	
		Primary Coarse Bed.	Secondary Coarse Bed.	Primary Coarse Bed.	Secondary Fine Bed.		Primary Coarse Bed.	Secondary Coarse Bed.	Primary Coarse Bed.	Secondary Fine Bed.
1899.										
Oct. 2	Nil.	0.2100	0.0560	0.1820	0.0182	0.2431	1.0343	1.5156	1.0412	0.6947
3	"	0.1680	0.0420	0.5600	0.0140	0.3503	1.9750	2.6961	0.9251	2.5524
4	"	0.1400	0.1120	0.2100	0.0210	0.3499	2.2200	2.3530	0.3931	2.0846
5	"	0.1400	0.0210	0.1260	0.0210	0.2053	1.3352	1.0798	2.3817	1.4421
6	"	0.1400	0.0210	0.0820	Nil	0.4218	2.1900	2.2350	2.1775	2.2500
7	"	0.0210	0.2800	0.0210	0.0280	0.3691	0.7216	0.9792	0.4841	1.5577
13	"	0.1400	0.0210	0.2100	0.0140	0.2441	1.4467	2.1194	0.8775	1.1940
14	"	0.0182	0.7000	Nil	0.0210	0.2317	1.8474	1.7881	0.8274	1.0501
16	"	0.0420	0.0280	0.0350	Nil	0.2978	1.2051	1.8431	1.3311	1.5583
17	"	0.0630	0.0280	0.1400	0.0140	0.3559	1.1960	0.9313	1.1892	0.9594
18	"	0.0210	0.0420	0.0560	0.0140	0.1810	0.2205	0.7604	0.2456	1.7178
19	"	0.1120	0.0280	0.0840	0.0140	0.2046	0.2530	1.0307	0.1188	3.0485
20	"	0.1400	0.0210	0.1120	0.0182	0.2270	0.1693	0.9627	0.4228	2.8098
21	"	0.0140	0.1400	0.0140	0.0350	0.2263	0.2289	0.5935	0.2289	1.8477
23	"	0.0210	0.0420	0.0140	0.0210	0.2399	0.4105	0.7126	0.2955	1.6935
24	"	0.0210	0.0280	0.0210	0.0280	0.2421	0.3438	0.8054	0.2760	2.1342
25	"	0.0140	0.0700	0.0210	0.0350	0.0847	0.2280	0.8907	0.2282	2.3750
26	"	0.1820	0.0280	0.0182	0.0420	0.1070	0.2196	0.9457	0.2834	1.6542
28	"	0.0140	0.0560	0.0140	0.0350	0.0799	0.1653	0.3533	0.2135	0.9708
30	"	0.0350	0.0140	0.0280	0.0140	0.0540	0.5816	1.2142	0.0773	1.5827
31	"	0.1120	0.0140	0.0210	Nil	0.0607	0.0093	0.4858	0.1661	1.6225
Nov. 1	"	0.0280	0.0182	0.0560	0.0140	0.3073	1.0840	1.4178	1.1350	1.9972
2	"	0.0140	0.0420	0.0140	0.0140	0.1791	0.2824	1.4140	0.1627	1.5766
3	"	0.1820	0.0700	0.0140	Nil	0.1199	0.1513	0.8537	0.2941	2.1005
4	"	0.0210	0.0280	0.0840	0.0140	0.0623	0.4766	1.2141	0.1023	2.2298
6	0.280	0.1400	0.0210	0.1120	Nil	0.4670	1.1637	1.9533	0.7517	2.2690
7	Nil	0.1400	0.0280	0.1400	0.0140	0.0593	0.6595	1.3960	0.4718	2.0730
8	"	0.1400	0.0280	0.1400	Nil	0.0585	0.5250	1.2161	0.2343	1.7410
9	"	0.2100	0.0560	0.1400	0.0182	0.2452	0.1681	0.9638	0.1661	1.6943
10	"	0.2100	0.0420	0.2800	Nil	0.1215	0.5209	1.7887	0.3290	1.7000
13	"	0.1400	0.0280	0.1400	0.0210	0.0603	0.5974	1.4260	0.5656	2.3280
14	"	0.2100	0.0420	0.2100	0.0280	0.1245	0.1531	1.6210	0.4025	1.8100
15	"	0.2100	0.0350	0.1400	0.0210	0.1837	0.1610	1.2037	0.3513	2.4100
16	"	0.2100	0.0350	0.2100	0.0210	0.2240	0.0140	0.6250	0.1666	1.9890
17	"	0.2100	0.0420	0.1400	0.0560	0.0549	0.1575	0.9620	0.0458	1.5620
18	"	0.0560	0.1400	0.0280	0.0560	Trace	0.2165	0.7337	0.1570	1.6520
20	"	0.2800	0.0420	0.2800	0.0280	0.0596	0.1738	1.3190	0.1469	2.8720
21	"	0.2100	0.0420	0.2100	0.0210	0.1212	0.5291	1.2992	0.0338	2.6660
22	"	0.0420	0.0560	0.0840	0.0420	0.0579	0.1036	1.0973	0.0616	2.3630
23	"	0.0700	0.0420	0.0280	0.1400	0.1813	0.5311	1.1513	0.2456	1.9016
24	"	0.0560	0.0420	0.0420	0.1400	0.1829	0.2520	0.8115	0.2545	1.6421
25	0.0140	0.0560	0.1680	0.0280	0.0560	0.0448	0.1792	0.2734	0.1754	1.1978
27	Nil	0.0210	0.0420	0.0140	0.0420	0.0605	0.0700	0.8155	0.0485	0.9348
28	"	0.1190	0.0490	0.0252	0.0560	0.1168	0.0066	1.3603	0.1023	0.0721
29	0.0140	0.0280	0.0378	0.0182	0.0378	0.0472	0.1132	1.3684	0.1043	0.2153
30	0.0140	0.1820	0.0280	0.0322	0.0322	0.0466	Lost	1.3570	0.1184	1.5303
Dec. 1	Nil	0.0700	0.0840	0.0140	0.0350	0.1203	0.7335	0.6685	0.1090	1.9817
2	"	0.0280	0.2100	0.0210	0.0700	0.1202	0.2118	0.6193	0.1601	1.6980
4	0.0280	0.2100	0.0280	0.0280	0.0280	0.2138	0.2211	1.4407	0.2188	2.0555
5	Nil	0.2100	0.0840	0.0210	0.0420	Nil	0.2878	1.1028	0.1604	2.4463
7	"	0.0210	0.0280	0.0140	0.0210	0.1198	0.1588	0.4693	0.2930	0.8491
8	"	0.0280	0.0210	0.0210	0.0140	0.2420	0.5795	1.2983	0.2210	1.6136
9	"	0.0420	0.1400	0.3500	0.0210	Trace	0.1980	0.7150	0.0116	1.5865
11	"	0.0140	0.0210	0.0420	0.0420	0.2379	0.2965	1.2190	0.3304	1.5128
12	"	0.0280	0.1400	0.0420	0.0210	0.3688	0.7131	0.7201	0.5714	1.8435
13	"	0.0280	0.0560	0.0280	0.0140	0.1758	0.1478	0.5560	0.1930	1.3376
14	"	0.1400	0.0280	0.0280	0.0210	0.2450	0.2192	0.2312	0.0912	1.2240
15	"	0.0210	0.0560	0.0210	0.0210	0.0622	0.1255	0.3023	0.2913	0.8119
16	"	0.0210	0.2100	0.0210	0.1400	0.2333	0.3916	0.3881	0.2258	0.5645
18	"	0.1400	0.0280	0.1400	0.0420	0.1196	0.2203	0.5663	0.0390	1.3278
19	"	0.1050	0.1050	0.0420	0.0420	0.0595	0.4968	0.6138	0.1998	1.2833
20	"	0.0420	0.2100	0.0280	0.0420	0.0606	0.1401	0.1228	0.2123	1.1573
21	0.0420	0.0280	0.1400	0.0280	0.0420	0.0173	0.1523	0.1627	0.3317	0.2553
22	Nil	0.0140	0.0280	0.0280	Nil	0.1001	0.1868	0.3335	0.2113	1.0656
27	0.0560	0.0840	0.0210	0.0560	0.0210	0.0612	0.0360	0.6992	0.0475	1.2004
28	Nil	0.0560	0.0210	0.0140	0.0140	0.0571	0.1224	0.4473	0.2210	1.2403
29	"	0.0210	0.0420	0.0140	0.0280	0.1129	0.3213	0.5370	0.2719	1.2833
30	"	0.0140	0.1050	0.0140	0.0420	0.0611	0.1266	0.1303	0.1019	1.2325
Averages	0.004	0.0932	0.0767	0.0645	0.0409	0.1602	0.4474	0.9279	0.3562	1.5861

It is worthy of note that after the beds had rested on Sundays an increased amount of nitrate was found in the Monday effluent. There can be little doubt that this additional nitrate was produced during the Sunday's rest, and was washed by the first effluent after the period of rest. This result was specially marked in the case of the secondary beds.

TABLE 6.—NUMBER OF TIMES THE COKE-BEDS OF SERIES A AND B WERE FILLED EACH DAY, AND THE AMOUNT OF OXYGEN ABSORBED BY THE CRUDE SEWAGE AND BY THE CORRESPONDING COKE-BED EFFLUENTS.

Date, 1899.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in four hours by one gallon of				
		Crude sewage.	Effluent from series A.		Effluent from series B.	
			Primary coarse bed.	Secondary coarse bed.	Primary coarse bed.	Secondary fine bed.
July 4th	Once	4.712	2.971	1.827	2.692	0.769
" 5th	"	4.615	3.269	1.827	2.596	0.865
" 6th	"	3.846	2.885	1.731	2.500	0.865
" 7th	"	4.135	2.500	1.731	2.692	0.769
" 8th	"	3.942	2.404	1.635	2.500	0.672
" 11th	"	3.750	3.077	2.115	2.212	0.769
" 12th	"	4.327	2.971	1.731	3.269	0.500
" 13th	"	4.327	2.692	1.635	2.971	0.672
" 14th	"	3.942	2.971	1.731	3.077	0.577
" 15th	"	4.423	2.596	1.346	2.692	0.672
" 17th	"	4.190	2.571	1.714	2.762	0.762
" 19th	"	4.476	2.857	2.857	2.952	1.909
" 21st	"	3.714	1.619	0.857	1.428	0.857
" 24th	"	3.908	2.285	1.809	2.476	0.761
" 26th	"	3.789	1.684	1.684	2.526	0.438
" 28th	"	4.210	2.315	1.263	2.241	0.438
" 31st	"	4.742	2.680	1.753	2.887	0.825
August 2nd	"	3.918	2.268	1.649	2.474	0.722
" 4th	"	4.330	2.680	1.856	2.680	0.825
" 9th	"	3.196	2.577	1.237	2.577	0.825
" 11th	"	3.228	2.187	1.237	1.666	0.833
" 14th	"	4.700	2.800	1.500	2.600	0.700
" 16th	"	4.100	2.800	1.900	2.800	0.800
" 18th	"	3.600	2.000	2.300	2.100	0.800
" 21st	"	4.791	2.400	1.562	2.500	0.937
" 23rd	"	4.583	2.604	1.354	2.604	1.041
" 25th	"	4.791	2.500	1.458	2.291	1.145
" 28th	"	2.688	2.043	1.387	2.150	0.968
" 30th	"	3.978	2.258	1.387	2.043	0.860
September 1st	"	4.387	2.427	2.142	1.436	1.020
" 4th	"	4.842	1.474	0.737	2.526	0.947
" 6th	"	4.687	2.812	1.875	2.708	0.937
" 8th	"	4.787	1.809	1.596	2.553	0.957
" 11th	"	4.105	2.842	1.684	2.421	0.947
" 13th	"	5.263	2.421	1.474	2.526	0.947
" 15th	"	4.255	2.340	1.489	2.234	0.745
" 18th	"	4.680	2.659	1.170	2.234	0.851
" 21st	"	4.680	3.085	1.255	2.125	1.170
" 22nd	"	4.255	1.595	1.276	1.702	0.744
" 23rd	"	4.042	1.595	1.489	1.489	0.851
" 25th	"	4.361	2.659	1.808	2.659	0.744
" 26th	"	4.255	2.453	1.489	2.125	0.957
" 27th	"	4.680	3.085	1.914	2.659	1.255
" 28th	"	4.479	2.708	1.770	2.604	1.250
" 29th	"	4.583	2.916	1.770	2.812	1.458
October 2nd	"	4.895	3.541	1.979	3.854	0.833
" 3rd	"	4.631	1.786	1.489	2.812	0.947
" 4th	"	4.315	2.812	1.894	3.368	1.263
" 5th	"	4.631	2.659	1.474	2.812	1.157
" 6th	"	4.631	2.526	1.489	2.000	0.947
" 7th	"	3.568	2.421	1.894	2.812	0.842
" 13th	"	4.903	2.500	1.634	3.076	1.153
" 14th	"	4.903	2.798	2.692	2.980	0.865
" 16th	"	3.173	1.923	1.346	1.538	0.961
" 17th	"	4.615	2.403	1.826	2.596	0.961
" 18th	"	4.444	2.500	1.730	2.403	1.153
" 19th	"	4.653	1.584	0.990	2.277	0.990

TABLE 6.—(continued).

Date, 1899.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of—				
		Crude sewage.	Effluent from series A.		Effluent from series B.	
			Primary coarse bed.	Secondary coarse bed.	Primary coarse bed.	Secondary fine bed.
October 20th ...	Once ...	3·861	2·178	1·287	1 584	0·792
" 21st ...	" ...	4·059	1·881	1·386	2·574	0·990
" 23rd ...	" ...	4·215	2·745	1·764	2·352	0·980
" 24th ...	" ...	4·313	2·549	1·470	2·549	1·078
" 25th ...	" ...	4·411	2·549	1·764	2·451	0·980
" 26th ...	" ...	4·411	2·156	1·078	2·647	0·980
" 28th ...	" ...	3·235	1·764	1·372	2·254	0·784
" 30th ...	" ...	2·843	1·470	0·892	1·274	0·588
" 31st ...	" ...	4·803	2·352	1·372	2·156	0·882
November 1st ...	" ...	4·509	1·961	1·176	2·254	0·882
" 2nd ...	" ...	5·294	2·843	1·764	2·352	0·980
" 3rd ...	" ...	4·313	2·745	1·570	1·961	0·882
" 4th ...	" ...	1·764	1·274	0·882	1·078	0·588
" 6th ...	" ...	2·156	1·176	0·784	1·078	0·686
" 7th ...	" ...	3·431	1·860	1·176	1·764	0·882
" 8th ...	" ...	2·941	1·570	1·372	1·078	0·588
" 9th ...	" ...	4·216	2·254	1·470	2·156	0·980
" 10th ...	" ...	2·843	1·863	1·078	1·667	0·686
" 13th ...	" ...	2·745	1·667	1·078	1·470	0·882
" 14th ...	" ...	4·803	2·745	1·372	2·156	1·078
" 15th ...	" ...	4·000	2·300	1·800	2·100	0·900
" 16th ...	" ...	4·400	2·700	1·300	2·200	1·100
" 17th ...	" ...	4·900	2·600	1·600	2·300	1·000
" 18th ...	" ...	4·100	3·400	1·800	2·500	0·900
" 20th ...	" ...	4·400	2·500	1·900	2·400	0·900
" 21st ...	" ...	4·117	2·352	1·568	2·745	0·882
" 22nd ...	" ...	4·607	2·745	1·667	2·549	0·882
" 23rd ...	" ...	4·215	2·254	1·372	2·254	1·274
" 24th ...	" ...	5·000	2·156	2·058	2·549	1·372
" 25th ...	" ...	4·059	2·277	1·386	2·277	1·089
" 27th ...	" ...	4·950	3·366	2·376	3·366	1·584
" 28th ...	" ...	7·100	1·500	1·600	2·500	1·300
" 29th ...	" ...	5·500	3·200	1·900	3·400	1·600
" 30th ...	" ...	4·500	2·200	1·700	2·800	1·200
December 1st ...	" ...	4·900	1·600	1·800	2·700	1·400
" 2nd ...	" ...	4·100	2·200	1·700	2·400	1·300
" 4th ...	" ...	5·000	3·000	2·000	2·900	1·200
" 5th ...	" ...	5·100	3·000	1·900	3·100	1·500
" 7th ...	" ...	4·653	2·574	1·683	2·772	1·287
" 8th ...	" ...	5·148	2·178	1·584	2·178	1·386
" 9th ...	" ...	4·300	2·500	1·700	2·300	1·200
" 11th ...	Twice...	4·500	2·400	1·700	1·800	1·300
" 12th ...	" ...	5·100	2·800	2·000	2·500	1·300
" 13th ...	" ...	5·100	2·700	1·800	2·500	1·200
" 14th ...	" ...	4·800	2·500	1·800	2·600	1·300
" 15th ...	" ...	4·100	1·900	1·700	2·800	1·500
" 16th ...	" ...	4·700	3·100	1·600	2·700	1·600
" 18th ...	" ...	4·300	2·100	1·700	2·100	1·400
" 19th ...	" ...	4·300	1·300	1·300	2·200	1·300
" 20th ...	" ...	5·300	2·900	2·000	3·000	1·700
" 21st ...	" ...	3·500	2·800	1·900	2·600	2·700
" 22nd ...	" ...	5·600	2·800	2·100	3·100	1·600
" 27th ...	" ...	4·700	3·300	1·700	2·700	1·600
" 28th ...	" ...	4·500	2·400	1·800	2·400	1·200
" 29th ...	" ...	4·900	2·500	2·000	3·400	1·500
" 30th ...	" ...	3·200	2·200	1·600	2·100	1·000
Averages ...		4·314	2·422	1·616	2·424	1·027

TABLES 7.—PARTICULARS OF THE TREATMENT OF SEDIMENTED CHEMICAL EFFLUENT IN THE
ONE ACRE COKE-BED.

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1898.									
May 12									818,680
" 13									743,341
" 14									717,669
" 16		2·871				0·564			748,903
" 17		4·700				0·844			705,782
" 18		4·100				0·917			732,699
" 19		2·500				0·531			702,605
" 20		2·100				0·469			719,532
" 21		2·300				0·469			695,500
" 23		2·700				0·569			695,500
" 25		3·000	Nil	0·0029		0·520	0·0280	0·0873	749,000
" 26		3·300	"	0·0017		0·630	0·1050	Nil	695,500
" 27		2·100	"	0·0059		0·480	0·0140	0·2166	722,250
" 28									722,250
" 31									749,000
June 1		2·600	"	0·0170		0·480	0·0210	0·0943	722,250
" 2		2·500	"	0·0115		0·460	0·0140	0·0780	703,161
" 3		2·500	"	0·0173		0·470	0·0182	0·0971	722,250
" 4		2·200	"	Nil		0·480	0·0210	0·1058	722,250
" 6		2·800	"	"		0·470	0·0140	0·1013	728,274
" 7		3·600	"	0·0115		0·690	0·0140	0·1186	722,250
" 8		2·800	"	Nil		0·540	0·0182	0·1086	712,205
" 9		2·900	"	"		0·500	0·0210	0·1116	722,250
" 10		3·000	"	"		0·471	0·0210	0·0943	722,250
" 11		2·200	"	"		0·412	0·0210	0·2096	695,500
" 13		2·900	"	"		0·519	0·0140	0·2570	722,250
" 14		3·800	"	0·0217		0·577	0·0252	0·2342	678,048
" 15		3·700	"	0·0115		0·663	0·0280	0·1450	678,048
" 16		3·100	"	0·0173		0·620	0·0322	0·0716	668,750
" 17		2·400	"	0·0115		0·490	0·0182	0·0738	668,750
" 18		2·000	"	Nil		0·460	0·0350	0·0976	678,048
" 20		2·300	"	"		0·510	0·0420	0·1136	695,500
" 21		2·500	"	"		0·578	0·0280	0·1161	668,750
" 22		2·900	"	0·0115		0·520	0·0280	0·0758	668,750
" 23		2·800	"	0·0404		0·519	0·0210	0·0943	642,000
" 24		2·600	"	Nil		0·500	0·0182	0·1374	605,553
" 25		1·800	"	"		0·462	0·0210	0·0712	642,000
" 27		2·500	"	"		0·481	0·0210	0·0655	668,750
" 28		2·500	"	"		0·425	0·0210	0·0655	642,000
" 29		2·800	"	"		0·453	0·0182	0·1893	642,000
" 30		2·300	"	"		0·442	0·0210	0·1002	642,000
July 1		2·300	"	"		0·463	0·0210	0·1231	642,000
" 2		1·600	"	"		0·505	0·0378	0·0948	642,000
" 4		2·200	"	"		0·432	0·0210	0·0943	652,700
" 5		3·000	"	"		0·545	0·0518	0·0922	642,000
" 6		2·800	"	0·0461		0·596	0·0182	0·0692	642,000
" 7		3·100	"	Nil		0·667	0·0140	0·0494	631,300
" 8		3·000	"	"		0·657	0·0148	0·0601	628,658
" 9									636,650
" 11		3·500	"	0·0173		0·634	0·0182	0·0798	642,000
" 12		3·500	"	Nil		0·683	0·0322	0·1350	502,900
" 13		3·600	"	0·0230		0·677	0·0252	0·1477	486,850
" 14		3·400	"	0·0173		0·635	0·0196	0·0957	466,667
" 15		3·200	"	Nil		0·667	0·0210	0·0193	540,350
									460,287
									632,177
									588,500
									599,200
									588,500
									622,800
									593,850

No record as regards total oxidisable matter.

No record as regards total oxidisable matter.

TABLE 7—(continued).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1898. July 16		2.200	Nil	Nil		0.633	Trace	Nil	615,250
" 18		1.700	"	"		0.571	0.0322	0.0139	604,550
" 19		3.000	"	"		0.663	0.0350	0.0226	615,250
" 20		2.500	"	"		0.633	0.0238	0.0742	587,330
" 21		2.700	"	"		0.633	0.0182	0.0740	649,640
" 22		2.276	"	"		0.630	0.0233	0.0511	369,919
" 23		2.178	"	"		0.540	0.0168	0.0524	406,600
" 25		3.069	"	0.0173		0.670	0.0238	0.0086	620,326
" 26		3.960	"	Nil		0.720	0.0210	0.0230	609,900
" 27		2.475	"	"		0.680	0.0210	0.0346	596,285
" 28		2.574	"	0.0115		0.600	0.0168	0.0230	612,755
" 29		3.366	"	Nil		0.570	0.0168	0.1326	571,982
Nov. 8	4.950	3.663	Nil	0.0987	1.089	0.649	0.1190	1.8129*	587,642
" 9	4.950	3.762	"	0.2006	1.089	0.505	0.1190	0.8697	556,400
" 10	4.950	3.366	"	0.1312	0.990	0.567	0.0700	0.7211	588,500
" 11	7.921	3.010	"	0.0969	0.693	0.557	0.0560	0.5171	569,106
" 12	4.950	3.366	"	0.1444	1.089	0.557	0.0840	0.2729	561,750
" 14	3.960	3.564	"	0.0075	0.990	0.569	0.0182	0.7212	695,500
" 15	4.950	3.960	"	0.0431	1.089	0.539	0.0182	0.6555	668,750
" 16	4.950	3.663	"	0.0937	0.990	0.539	0.0210	0.5952	722,250
" 17	3.960	3.465	"	0.1131	0.990	0.577	Trace	0.5562	668,750
" 18	4.950	3.456	"	0.0525	0.891	0.547	Trace	0.4025	668,750
" 19	5.000	3.500	"	0.2437	1.300	0.629	0.0160	0.2877	676,130
" 21	5.000	4.000	"	0.0700	1.200	0.581	0.0140	0.7110	668,750
" 22	7.000	5.300	0.0490	0.0829	1.200	0.619	0.0140	0.8385	695,500
" 23	7.000	5.200	Trace	0.1094	0.700	0.619	0.0140	0.4347	652,700
" 24	7.000	5.000	Nil	0.0244	1.500	0.707	0.0182	0.3687	625,950
" 25	5.000	3.500	0.0350	Lost	1.200	0.535	0.0180	0.1937	642,003
" 26	3.000	2.400	Nil	0.0375	0.900	0.510	0.0140	0.4754	636,650
" 28	5.000	3.900	"	0.0687	1.000	0.570	0.0238	0.5549	631,300
" 29	5.000	3.900	0.0350	Nil	0.800	0.520	0.0210	0.7065	597,562
" 30	6.000	4.000	Nil	0.0237	1.100	0.627	0.0210	0.3396	615,250
Dec. 1	6.000	4.300	"	0.0806	1.000	0.529	0.0140	0.5672	674,100
" 2	7.000	5.100	Trace	0.0319	1.100	0.559	0.0182	0.5593	636,650
" 3	6.000	3.600	Nil	0.1362	1.300	0.618	0.0350	0.3394	631,300
" 5	6.000	5.000	"	—	1.300	0.702	0.0210	—	663,400
" 6	6.000	5.300	"	0.1606	1.200	0.635	0.0210	0.6415	615,250
" 7	5.000	3.400	0.1190	0.0841	1.000	0.529	0.0252	0.7494	603,252
									574,797
									580,488

* This large amount of nitrate, as compared with that found on July 29th, had probably been produced during the period of resting, and was washed out in the first effluent.

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1898.									
Dec. 8	5.000	3.500	0.6300	Nil	1.100	0.551	0.0280	0.6420	574,797
" 9	4.000	3.800	0.0560	0.0221	0.800	0.551	0.0210	0.4690	557,506
" 10	4.000	3.800	Trace	0.0656	0.900	0.622	0.0280	0.3420	605,676
" 12	6.000	4.500	"	0.0737	0.900	0.550	0.0210	0.7502	524,300
" 13	6.000	4.700	0.0140	Nil	1.200	0.640	0.0238	0.3468	588,500
" 14	4.000	2.700	0.0490	"	0.700	0.530	0.0210	0.4040	583,150
" 15	5.000	4.300	0.0420	"	1.100	0.620	0.0238	0.2199	588,500
" 16	5.000	4.800	0.0070	0.0199	1.100	0.650	0.0280	0.1507	540,350
" 17	4.000	3.700	Nil	0.0806	2.300	0.630	0.0378	0.1759	540,651
" 19	6.000	4.700	0.0112	0.1363	1.300	0.690	0.0280	0.3395	569,106
" 20	6.000	5.300	0.0210	0.1059	1.200	0.683	0.0238	0.3512	552,033
" 21	6.000	5.200	0.0112	0.1063	1.200	0.702	0.0420	0.1967	558,724
" 22	7.000	5.100	Trace	0.6375	1.400	0.712	0.0182	0.1462	567,100
" 23	6.000	5.400	Nil	0.0394	1.300	0.697	0.0140	0.1522	540,350
" 24	3.000	2.900	0.1400	0.3062	1.000	0.545	0.0376	1.1676	545,700
" 28									567,100
" 29	4.000	3.800	0.0700	0.1362	1.100	0.545	0.0182	0.3093	524,300
" 30	3.000	2.600	0.0560	0.0802	2.000	0.762	0.0322	0.2228	588,500
" 31	6.000	4.100	Nil	0.0231	Lost	0.663	0.0182	0.1143	535,000
1899									535,000
Jan. 2	5.880	4.118	0.1400	Nil	1.473	0.577	0.0210	0.5259	535,000
" 3	6.860	4.706	0.0070	0.0417	1.276	0.663	0.0210	0.5877	545,700
" 4	7.000	4.500	Nil	0.0337	1.400	0.635	0.0420	0.2011	535,000
" 5	7.000	4.600	0.1190	Nil	1.400	0.712	0.1050	0.0675	518,950
" 6	7.000	4.600	0.0240	"	1.500	0.683	0.0700	Nil	569,764
" 7	6.000	4.200	Nil	0.0344	1.200	0.606	0.0910	0.0959	561,750
" 9	10.000	4.800	0.0140	0.1047	1.300	0.400	0.0840	0.0822	561,750
" 10	6.000	4.300	0.0182	0.0112	1.300	0.680	0.0742	0.1183	540,350
" 11	4.000	2.500	0.1400	Nil	1.300	0.580	0.0350	0.2606	535,000
" 12	4.000	2.700	0.1050	"	1.000	0.610	0.0210	0.2190	545,700
" 13	3.000	3.200	0.2800	"	0.900	0.580	0.0560	0.3084	561,750
" 14	4.000	2.700	0.1050	"	1.000	0.560	0.0420	0.5275	540,350
" 16	4.000	3.300	0.3500	"	1.000	0.560	0.0490	0.6667	535,000
" 17	4.000	3.600	0.2100	"	1.000	0.570	0.0420	0.5380	545,700
" 18	8.000	5.400	0.1050	"	1.400	0.750	0.0280	0.5451	540,350
" 19	6.000	4.100	0.1190	"	1.200	0.654	0.0420	0.3811	521,224
" 20	5.000	4.800	0.0280	"	1.300	0.635	0.0140	0.2872	529,067
									537,206
									533,137

TABLE 7—(continued).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899.									
Jan. 21	5.000	2.600	Nil	Trace	1.100	0.606	0.0420	0.5017	540,350
" 23		1.980	0.1610	Nil		0.413	0.0322	0.8640	551,050
" 24		3.366	0.1330	"		0.452	0.0280	0.5970	561,750
" 25		3.267	0.0280	"		0.442	Trace	0.5781	561,750
" 26		3.900	0.0140	0.0654		0.557	0.0140	0.2922	529,650
" 27		3.600	0.0210	0.0309		0.546	0.0140	0.1947	561,750
" 28		3.100	Nil	0.1456		0.515	0.0140	0.7879	535,000
" 30		4.300	"	Trace		0.660	0.0238	0.1524	561,750
" 31		5.100	0.0420	0.0767		0.700	0.0210	0.1146	529,067
Feb. 1		5.400	0.0140	0.0422		0.800	0.0140	0.0854	551,050
" 2		5.500	Nil	0.0437		0.840	0.0210	0.1027	545,700
" 3		5.000	"	Trace		0.800	0.0210	0.0890	529,067
" 4		4.500	"	"		0.740	0.0280	0.1532	551,050
" 6		4.300	0.1050	Nil		0.680	0.0140	0.2379	545,700
" 7		3.800	0.1260	0.1052		0.630	0.0350	0.1937	540,350
" 8		3.300	0.0910	Nil		0.693	0.0210	0.0877	535,000
" 9		1.400	0.1750	1.0356		0.500	0.0560	0.5996	502,900
" 10		2.700	0.1400	0.0931		0.592	0.0308	0.2361	512,195
" 11		2.900	Nil	0.0512		0.604	0.0280	0.0510	518,950
" 13		3.100	0.0700	Nil		0.653	0.0210	0.3371	527,371
" 14		3.800	Nil	0.0162		0.704	0.0210	0.3377	507,280
" 15		4.200	0.0140	0.0285		0.690	0.0210	0.3102	481,500
" 16		3.900	0.1400	0.1062		0.720	0.0280	0.2682	497,235
" 17		4.500	0.0280	0.0914		0.710	0.0280	0.2351	497,235
" 18		4.200	Nil	0.0531		0.780	0.0280	0.0930	511,772
" 20		4.500	0.0210	0.0652		0.680	0.0210	0.2490	486,850
" 21		5.000	Nil	Trace		0.710	0.0140	0.1929	492,200
" 22		4.600	0.0140	0.0516		0.770	0.0210	0.0284	497,550
" 23		2.400	Trace	0.0900		0.620	0.0210	Nil	508,250
" 24		4.100	0.0350	0.0331		0.660	0.0280	"	502,382
" 25		3.800	Nil	0.1144		0.630	0.0420	0.0080	524,300
" 27		3.600	0.0420	0.0692		0.610	0.0280	0.0900	508,250
" 28		4.000	0.0140	0.0140		0.622	0.0280	0.2038	518,950
March 6		4.500	0.0140	0.0604		0.690	0.0350	0.7168	535,000
" 7		5.500	0.0070	0.0392		0.810	0.0280	0.2651	508,250
" 8		5.300	Nil	0.1944		0.800	0.0140	0.0866	492,439
									513,600
									518,950
									535,000
									508,250
									492,200
									497,550
									513,600
									518,950
									517,326
									508,250
									502,900
									518,950
									535,000
									508,250
									492,439
									513,600
									486,850
									508,250

TABLE 7—(continued).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899. March 9		5.600	0.0280	0.0370		0.870	0.0140	0.1572	486,850
" 10		4.400	0.0280	0.0857		0.720	0.0140	Nil	481,500
" 11		3.100	Nil	0.1337		0.660	0.0140	0.1510	487,190
May 8		2.885	Nil	0.1075		0.798	0.3500	10.5910	492,200
" 9		4.808	0.0070	0.1630		0.879	0.4200	7.9369	483,601
" 10		5.000	Nil	0.0450		0.919	0.2800	4.2037	657,322
" 15		2.115	"	0.1712		0.608	0.0462	4.3138	633,847
" 16		3.654	"	Nil		0.500	0.0700	2.4769	642,000
" 17		2.885	"	0.1662		0.476	0.0350	2.2525	615,250
" 18		3.010	"	0.1162		0.408	0.0308	1.4192	615,250
" 19		4.423	Trace	Trace		0.592	0.0420	1.4811	563,419
" 20									563,419
" 23									584,102
" 24		2.981	Nil	0.1100		0.524	0.0280	0.9570	563,419
" 25		2.404	"	0.1731		0.486	0.0238	0.7087	539,943
" 26		2.981	"	0.1206		0.467	0.0280	0.5276	521,224
" 27		2.788	"	0.0525		0.505	0.0350	0.4500	539,943
" 29		3.654	"	0.1168		0.476	0.0280	0.9957	563,419
" 30		4.327	"	0.1194		0.514	0.0462	1.1925	563,419
" 31		3.750	"	Nil		0.604	0.0322	0.6359	577,800
June 1		3.558	"	0.0662		0.584	0.0280	0.3826	539,943
" 2		3.077	"	0.1125		0.554	0.0280	0.6338	544,639
" 3		2.788	"	0.0187		0.535	0.0560	0.6752	567,100
" 5		3.654	0.0140	0.0747		0.554	0.0210	1.0665	567,100
" 6		3.173	Nil	0.0487		0.510	0.0210	0.6646	549,334
" 7		1.827	"	0.0737		0.451	0.0182	0.4049	551,750
" 8		2.855	"	0.1043		0.510	0.0210	0.1459	540,350
" 9		3.077	"	0.0675		0.471	Trace	0.2375	577,800
" 10		2.404	"	0.0618		0.500	0.0210	0.3277	545,700
" 12		3.173	0.0070	0.1011		0.490	0.0182	0.2780	472,090
" 13		3.269	Nil	0.0881		0.500	0.0238	0.5830	567,100
" 14		4.528	"	0.0681		0.667	0.0210	0.3015	549,334
" 15		4.423	"	0.0700		0.725	0.0420	0.2517	518,950
" 16		4.134	"	0.0262		0.725	0.0350	0.1975	544,638
" 17									529,650
" 19		4.423	"	0.0900		0.676	0.0210	0.7509	539,943
" 20		4.038	0.0042	0.0795		0.689	0.0350	0.6212	529,650
" 21		4.528	Nil	0.1400		0.621	0.0210	0.2127	539,943
" 22		2.788	"	0.0744		0.621	0.0210	0.1165	529,650
" 23		1.000	"	0.1394		0.466	0.0238	0.2393	539,943
" 24		3.173	"	0.0987		0.641	0.0350	0.1075	540,350
" 26		2.885	"	0.1944		0.600	0.0238	0.4149	549,333
" 27		3.269	"	0.0862		0.610	0.0280	0.3445	540,350
									530,553
									508,250
									511,772
									518,950
									516,468
									508,250
									532,393
									508,250
									530,553
									497,550
									502,382
									497,550
									527,371
									508,250
									527,371
									508,250
									492,200
									512,303

TABLE 7—(continued).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899. June 28		3·558	Nil.	0·1075		0·630	0·0280	0·5101	481,500
" 29		3·269	Trace	0·0381		0·640	0·0322	0·4447	502,900
" 30		2·788	Nil	0·1606		0·590	0·0280	0·3376	508,250
July 1		2·019	"	0·1337		0·530	0·0378	0·5684	551,050
" 3		3·365	"	0·0994		0·520	0·0238	0·6343	497,550
" 4		3·846	"	0·0537		0·529	0·0280	0·5170	502,900
" 5		3·558	"	0·0862		0·559	0·0280	0·3901	481,500
" 6		1·635	"	0·1137		0·451	Trace	0·2843	508,250
" 7		2·308	"	0·0562		0·539	0·0378	0·1865	535,000
" 8		1·827	"	0·1034		0·471	0·0308	0·1804	518,950
" 10		2·212	"	0·0650		0·500	0·0280	0·5657	508,250
" 11		2·971	"	0·0331		0·622	0·0238	0·1331	508,250
" 12		3·269	"	0·1037		0·674	0·0350	0·2437	447,672
" 13		2·971	"	0·1012		0·643	0·0350	0·2100	497,550
" 14		2·788	"	0·1387		0·582	Nil	0·2331	486,850
" 15		2·596	"	0·0337		0·674	0·0448	0·2064	527,371
" 17		3·048	"	0·2200		0·581	0·0252	0·5668	481,500
" 18		2·962	"	0·0787		0·612	0·0280	0·5890	492,992
" 19		2·962	"	Trace		0·581	0·0350	1·8051	492,200
" 20		2·761	"	"		0·561	0·0280	0·0980	488,297
" 21		2·381	"	"		0·551	0·0210	0·0984	513,600
" 22		1·619	"	0·0772		0·490	0·0238	0·1116	497,550
" 24		2·380	"	0·1758		0·514	0·0210	0·4592	486,850
" 25		3·238	"	0·2491		0·476	0·0210	0·2823	502,900
" 26		3·052	"	0·1807		0·609	0·0210	0·1620	508,250
" 27		3·052	"	0·1882		0·580	0·0252	0·4280	481,500
" 28		2·631	"	0·1206		0·628	0·0252	0·3384	481,500
" 29		Lost	"	0·2930		0·636	0·0210	0·3370	447,010
" 31		3·093	"	0·1791		0·555	0·0210	0·2208	455,811
Aug. 1		3·505	"	0·1796		0·572	0·0182	0·3408	446,040
" 2		2·268	"	0·2346		0·570	0·0210	0·3321	502,258
" 3		3·402	"	0·2392		0·580	0·0210	0·3951	422,564
" 4		3·505	"	0·1297		0·580	0·0128	0·2883	492,213
" 5									446,040
" 8		1·702	"	0·1785		0·534	0·0210	0·2456	399,605
									377,229
									416,979
									508,250
									481,500
									470,800
									481,500
									454,750
									481,500
									444,050
									470,800

TABLE 7—(continued).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899. Aug. 9		2·062	Nil.	0·1477		0·485	0·0140	0·2827	465,450
" 10		2·371	"	0·2415		0·485	0·0210	0·9540	465,450 470,800
" 11		2·500	"	0·3016		0·566	0·0182	0·4639	454,750 465,450
" 12		2·500	"	0·2378		0·639	0·0252	0·3377	454,750 470,800
" 14		2·700	"	0·2366		0·601	0·0210	0·2310	455,285 422,564
" 15		2·900	"	0·3696		0·592	0·0210	0·5131	454,750 422,564
" 16		2·900	"	0·0705		0·563	0·0210	0·4603	454,750 422,564
" 17		2·500	"	0·1186		0·533	0·0182	0·2235	492,200 422,564
" 18		2·400	"	0·1201		0·524	0·0182	0·2836	454,750 417,869
" 19		1·700	"	0·3603		0·512	0·0238	0·5799	460,100 427,259
" 21		2·083	"	0·1790		0·500	0·0210	0·3167	427,259 508,250
" 22		2·500	"	0·2986		0·521	0·0210	0·5723	422,564 470,800
" 23		2·916	"	0·1068		0·521	0·0210	0·3418	454,750 454,750
" 24		2·395	"	0·3582		0·574	0·0140	0·5841	454,750 460,100
" 25		2·812	"	0·3058		0·680	0·0128	0·5847	481,500 460,100
" 26		2·500	"	0·4112		0·667	0·0252	0·7454	406,975 460,100
" 28		3·226	"	0·2351		0·594	0·0140	0·3503	406,975 427,260
" 29		3·215	"	0·3611		0·625	0·0210	0·5769	481,500 454,750
" 30		2·796	"	0·0850		0·583	0·0140	0·2876	454,750 454,750
" 31		2·688	"	0·2398		0·427	0·0210	0·4607	454,750 481,500
Sept. 1		4·285	"	0·0620		0·670	0·0140	0·2258	454,750 422,564
" 2		2·526	"	0·2406		0·680	0·0210	0·4615	454,750
" 4		2·211	"	0·4737		0·503	0·0140	0·6966	481,500 454,750
" 5		2·812	"	0·3551		0·505	0·0140	0·5791	454,750 470,800
" 6		1·915	"	0·2996		0·670	0·0112	0·4643	422,564 422,564
" 7		2·340	"	0·4765		0·558	0·0182	0·5824	454,750 465,450
" 8		2·447	"	0·3558		0·579	0·0182	0·5718	454,750 460,100
" 9		3·469	"	0·2928		0·706	0·0210	0·5900	454,750 460,100
" 11		2·842	"	0·1081		0·645	0·0182	0·2243	422,564 481,500
" 12		2·316	"	0·2008		0·624	0·0182	0·4099	454,750 431,955
" 13		3·263	"	0·0491		0·763	0·0210	0·0972	460,100 422,564
" 14		2·128	"	0·2436		0·581	0·0182	0·3453	431,955 427,260
" 15		2·978	"	0·2378		0·354	0·0182	0·3411	465,450 408,479
" 16		2·446	"	0·2980		0·623	0·0210	0·6960	454,750 417,869
" 18		2·872	"	0·0720		0·494	0·0140	0·4628	419,184 431,955
									465,450

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899.									
Sept. 19		2·021	Nil.	0·2410		0·494	0·0140	0·3470	422,564
" 20		3·191	"	0·2916		0·634	0·0210	0·7043	455,285
" 21		3·404	"	0·2384		0·553	0·0280	0·7890	460,100
" 22		3·085	"	0·1315		0·559	0·0210	0·6045	454,750
" 23		3·095	"	0·3029		0·602	0·0182	1·0698	454,750
" 25		3·298	"	0·3586		0·505	0·0140	0·5726	454,750
" 26		3·723	"	0·2391		0·559	0·0182	0·4045	470,800
" 27		4·042	"	0·1930		0·602	0·0140	0·5900	481,500
" 28		3·229	"	0·1986		0·495	0·0140	0·4030	454,750
" 29		2·708	"	0·3460		0·580	0·0280	0·5715	454,750
" 30		2·187	"	0·3758		0·428	0·0210	0·5845	460,100
Oct. 2		3·645	"	0·3645		0·523	0·0182	0·6042	454,750
" 3		2·000	"	0·2385		0·452	0·0140	0·3491	455,285
" 4		2·812	"	0·6206		0·428	0·0182	1·4370	455,285
" 5		2·105	"	0·4320		0·750	0·0140	0·6018	460,100
" 6		2·812	"	0·4922		0·490	0·0140	0·8105	454,750
" 7		2·947	"	0·4800		0·600	0·0182	0·8236	449,400
" 9		2·812	"	0·1325		0·620	0·0140	0·4785	454,750
" 10		2·947	"	0·2912		0·700	0·0218	0·5882	470,800
" 11		3·654	"	0·3578		0·600	0·0218	0·5732	406,974
" 12		3·654	"	0·3936		0·660	0·0210	0·7047	454,750
" 13		4·038	"	0·3624		0·690	0·0210	0·5830	455,285
" 14		3·654	"	0·2224		0·660	0·0280	0·4586	449,400
" 16		3·461	"	0·1780		0·480	0·0210	0·4505	454,750
" 17		3·557	"	0·2417		0·605	0·0210	0·3975	431,955
" 18	3·365	2·211	"	0·3035	0·543	0·456	0·0140	0·4767	454,750
" 19	4·059	2·673	"	0·3728	0·620	0·500	0·0140	0·4765	460,100
" 20	3·663	2·475	"	0·3993	0·590	0·480	0·0182	0·5980	454,750
" 21	3·861	2·574	"	0·2486	0·610	0·450	0·0182	0·4047	454,750
" 23	4·507	3·431	"	0·1844	0·666	0·558	0·0140	0·3526	454,750
" 24	5·098	3·833	"	0·2359	0·764	0·607	0·0140	0·4683	441,987
" 25	5·000	3·725	"	0·1802	0·794	0·607	0·0210	0·3416	486,850
" 26	4·803	3·431	"	0·0977	0·754	0·598	0·0182	0·2171	465,450
" 27	4·215	3·431	"	0·0871	0·784	0·637	0·0182	0·2843	460,100
" 28	3·333	2·058	"	0·0300	0·663	0·500	0·0182	0·0607	454,750
" 30	3·725	2·549	"	0·0505	0·672	0·427	0·0140	0·0787	438,212
									454,750
									454,750

TABLE 7—(continued).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899. Oct. 31	5.294	3.725	Nil.	0.0592	0.618	0.518	0.0140	0.1381	449,400
Nov. 1	4.607	3.333	„	0.1846	0.690	0.545	0.0140	0.4785	454,750
„ 2	3.823	2.450	„	0.0565	0.520	0.429	0.0280	0.0905	454,750
„ 3	2.941	1.862	0.1120	0.0388	0.591	0.469	0.0182	0.3509	454,750
„ 4	1.960	1.078	0.0840	0.3460	0.540	0.387	0.0350	0.4618	460,100
„ 6	2.058	1.274	0.1120	0.2560	0.415	0.336	0.0280	0.3945	472,358
„ 7	3.333	2.549	0.5600	0.0525	0.574	0.455	0.0350	0.3340	455,285
„ 8	4.117	2.254	0.0420	0.3013	0.504	0.396	0.0210	0.5996	454,750
„ 9	3.137	2.254	0.0560	0.0867	0.554	0.445	0.0140	0.2923	460,100
„ 10	4.126	2.647	0.0700	0.2201	0.416	0.307	0.0210	0.3040	454,750
„ 11	2.647	1.764	Nil	Trace	0.526	0.419	0.0210	0.2133	454,750
„ 13	4.216	3.333	„	0.0603	0.616	0.482	0.0210	0.3324	422,564
„ 14	4.901	3.823	„	0.1224	0.660	0.526	0.0280	0.2717	422,564
„ 15	4.500	3.500	„	0.1806	0.634	0.461	0.0210	0.3491	422,564
„ 16	4.400	4.000	„	0.0973	0.596	0.480	0.0280	0.3370	347,482
„ 17	1.700	1.300	„	0.0354	0.443	0.413	0.0210	0.3541	422,564
„ 18	4.400	2.600	„	0.0675	0.634	0.480	0.0420	0.4360	422,564
„ 20	4.200	3.200	„	0.0596	0.586	0.471	0.0420	0.4560	465,450
„ 21	4.803	3.725	„	0.1810	0.622	0.513	0.0420	0.5680	454,750
„ 22	5.196	4.117	„	0.1146	0.651	0.522	0.0420	0.4154	422,564
„ 23	4.313	3.529	0.0560	0.2420	0.963	0.899	0.0700	0.6475	454,750
„ 24	4.705	3.529	Nil	0.3067	0.558	0.477	0.0560	0.4388	347,482
„ 25	4.356	3.465	„	0.0581	0.563	0.447	0.0420	0.1917	354,432
„ 27	5.248	4.455	„	0.0800	0.660	0.602	0.0140	0.5360	347,482
„ 28	5.800	4.500	0.0280	0.0333	0.702	0.615	0.0322	0.1540	465,450
„ 29	5.700	4.200	0.0140	0.0985	0.760	0.635	0.0322	0.0928	449,400
„ 30	5.500	4.300	0.0140	0.0170	0.712	0.635	0.0322	0.0102	454,750
Dec. 1	5.700	4.500	0.0322	0.0481	0.731	0.630	0.0210	0.1480	465,450
„ 2	3.300	2.200	Nil	0.3006	0.811	0.555	0.0210	0.4638	470,800
„ 4	3.900	2.600	0.0420	0.2041	Lost	0.666	0.0280	0.2766	465,450
„ 5	3.400	2.900	0.0280	0.3445	0.759	0.601	0.0210	0.5923	426,830
„ 6	4.200	3.700	Nil	0.0606	0.685	0.527	0.0210	0.2802	454,750
„ 7	5.445	4.059	„	0.0598	0.734	0.632	0.0210	0.2218	426,830
„ 8	5.148	4.059	0.0560	0.0635	0.663	0.561	0.0280	0.1010	455,285
„ 9	4.800	3.300	Nil	0.1231	0.650	0.620	0.0420	0.3251	432,521
„ 11	5.600	4.700	„	0.2481	0.740	0.670	0.0420	0.5714	454,750

TABLE 7—(continued).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899. Dec. 12	6·000	5·400	Nil	0·1172	0·740	0·700	0·0420	0·5473	454,750
„ 13	6·300	5·600	„	Trace	0·720	0·680	0·0350	0·2110	444,050
„ 14	5·200	4·900	„	0·2975	0·708	0·669	0·0420	0·3710	422,564
„ 15	4·900	4·300	0·0560	0·1300	0·660	0·583	0·0420	0·2547	449,400
„ 16	3·400	1·900	Nil	0·2493	0·349	0·349	0·0420	0·3236	454,750
„ 18	4·000	3·600	0·0560	0·0616	0·543	0·436	0·0420	0·2519	454,750
„ 19	4·300	3·400	0·0560	0·1808	0·485	0·405	0·0420	0·4155	454,750
„ 20	5·000	4·200	0·0560	0·0041	0·663	0·485	0·0350	0·3874	438,700
„ 21	5·200	4·000	0·0560	0·0546	0·574	0·465	0·0420	0·2688	422,564
„ 22	6·100	5·500	0·0420	0·1978	0·841	0·742	0·0280	0·3335	438,700
„ 27	6·100	4·900	0·0490	0·0710	0·723	0·523	0·0700	0·5400	454,750
„ 28	5·800	4·900	0·0560	0·0558	0·628	0·485	0·0210	0·5332	440,050
„ 29	5·300	4·300	0·0420	0·0691	0·828	0·666	0·0140	0·4425	454,750
„ 30	4·300	2·900	Nil	0·1167	0·543	0·467	0·0280	0·3802	454,750

AVERAGES.

Date.	Oxygen absorbed from permanganate in 4 hours.		Nitrogen as		Oxygen absorbed from permanganate in 4 hours.		Nitrogen as		Remarks.
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1898									
May 12—May 23		3·039				0·623			} One filling. Two fillings. One filling.
May 25—July 2		2·655	Nil	0·0059		0·509	0·0252	0·1145	
July 4—July 29		2·877	Nil	0·0061		0·624	0·0221	0·0615	
Nov. 8—Nov. 19	5·045	3·525	Nil	0·1114	1·018	0·567	0·0474	0·6738	
1899									
Nov. 21—Jan. 21	5·465	4·108	0·0610	0·0594	1·183	0·613	0·0321	0·3979	} Two fillings. Two fillings after first three weeks.
1899									
Jan. 23—Mar. 11		3·987	0·0396	0·0783		0·665	0·0233	0·2407	
May 8—Oct. 17		2·976	0·0003	0·1814		0·574	0·0308	0·7118	
Oct. 18—Dec. 30	4·443	3·393	0·0291	0·1411	0·642	0·529	0·0290	0·3483	
1898									
May 12—July 2		2·726	Nil	0·0059		0·530	0·0252	0·1145	One filling.
1899									
Nov. 21—Mar. 11	5·465	4·057	0·0518	0·0683	1·183	0·635	0·0283	0·3300	Two fillings.
1899									
May 8—Dec. 30	4·443	3·109	0·0095	0·1686	0·643	0·560	0·0302	0·5963	
1898 1899									
May 12—Dec. 30	4·921	3·306	0·0186	0·1158	0·900	0·580	0·0294	0·4531	Whole period.

PERCENTAGE PURIFICATION.

1898								
May 12—July 2						80·5		
1899								
Nov. 21—Mar. 11					78·4	84·3		
1899								
May 8—Dec. 30					85·5	82·0		

2.—CROSSNESS RESULTS.

TABLE 8.—DETAILS OF THE ANALYTICAL RESULTS OBTAINED FROM THE CRUDE SEWAGE AND THE EFFLUENT FROM THE BACTERIAL BEDS.

Date.	Crude sewage.				Coke-bed effluent.		
	Number of fillings per day.	Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as		Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as	
			Nitrite.	Nitrate.		Nitrite.	Nitrate.
1899.							
Feb. 27	One	3.039	Nil	Nil	1.614	0.014	Trace
28	"	4.300	"	"	2.500	Trace	"
Mar. 1	"	2.600	"	"	1.500	Nil	Nil
2	"	3.418	"	"	1.827	0.007	0.030
3	"	4.620	"	"	2.815	Trace	Nil
4	"	2.942	"	"	1.629	Nil	"
6	"	3.511	"	"	2.021	0.014	Trace
7	"	2.766	0.021	"	1.915	0.070	"
8	"	2.872	Trace	"	0.958	0.084	0.052
10	"	3.191	Nil	"	1.489	Nil	0.095
11	"	3.085	"	Trace	1.489	0.021	0.040
13	"	3.737	0.014	Nil	1.212	0.021	0.110
14	"	2.525	Nil	Trace	0.999	Trace	0.037
15	"	2.632	"	Nil	0.947	Nil	Trace
16	"	3.263	"	"	1.158	"	0.077
17	"	2.947	"	"	1.158	0.021	Trace
18	"	3.158	"	"	1.370	0.035	0.136
20	"	2.604	"	"	1.042	0.070	Trace
21	"	4.271	"	"	1.562	0.014	0.143
22	"	6.459	Trace	"	3.125	0.021	0.083
23	"	3.263	0.007	"	1.369	0.014	0.071
24	"	4.062	Nil	"	1.770	0.007	0.128
25	"	2.917	"	"	1.042	0.021	0.114
27	Two	3.036	Trace	"	1.518	Nil	0.142
28	"	3.482	Nil	"	1.875	0.021	Nil
29	"	2.679	"	"	1.429	0.007	0.109
April 4	"	3.100	"	"	1.400	0.042	Trace
5	"	2.000	"	"	1.200	0.014	0.123
6	"	3.200	Trace	"	1.800	Nil	0.038
7	"	2.800	0.028	0.011	1.400	0.007	0.080
8	One	2.700	Nil	Nil	1.500	0.014	0.078
10	Two	3.725	0.014	"	1.961	0.007	0.056
11	"	3.039	Nil	"	1.470	0.014	0.213
12	"	4.314	Trace	"	2.568	0.070	0.044
13	"	2.451	0.007	Trace	1.372	Nil	0.081
14	"	3.921	Nil	Nil	2.451	0.014	0.060
15	One	3.137	0.021	"	1.862	0.014	0.138
17	"	4.301	Nil	"	2.680	0.028	0.136
18	Two	3.824	0.007	Trace	2.680	0.014	0.054
19	"	2.574	Trace	Nil	1.453	0.042	0.285
20	"	5.247	Nil	"	3.014	Nil	Trace
21	"	4.444	"	"	2.525	0.014	0.184
22	One	4.646	0.021	"	3.030	0.007	0.253
24	Two	3.878	0.028	Trace	2.245	0.014	0.210
25	"	2.653	Trace	Nil	1.617	Trace	Trace
26	"	2.842	Nil	"	1.789	Nil	0.322
27	"	2.857	"	Trace	1.667	0.021	0.148
28	"	4.742	0.007	0.034	2.755	0.056	0.180
29	One	3.542	0.007	Nil	2.371	0.042	Trace
May 1	Two	2.846	0.014	"	1.579	Trace	0.170
2	"	2.340	Nil	"	1.474	0.070	0.094
3	"	3.298	"	"	1.959	0.021	0.208
4	"	4.480	"	"	2.660	Nil	0.045
5	One	3.830	Trace	"	2.340	0.007	0.241
6	"	3.300	0.007	Trace	1.800	0.014	Trace
8	Two	4.216	Nil	"	2.451	Nil	0.180
9	"	3.301	"	Nil	1.863	Trace	0.094
10	"	2.277	"	"	1.078	0.056	0.231
11	"	2.784	"	"	1.443	0.070	Trace
12	One	3.299	"	"	1.735	0.014	Nil
13	"	2.143	"	"	1.237	0.028	0.113
15	Two	3.535	"	"	1.919	0.028	Nil
16	"	4.124	"	"	2.755	Trace	"
17	"	2.300	"	"	1.400	0.007	0.204
18	"	3.800	0.035	"	2.000	0.098	0.046
19	"	1.700	Nil	"	0.800	0.021	0.133
24	"	4.255	"	"	2.553	0.042	0.320
25	"	3.298	"	"	1.702	0.070	0.055
26	"	2.826	"	"	1.277	0.070	0.121
27	One	2.766	"	"	1.596	0.084	0.219
29	Two	2.632	0.014	"	1.579	0.035	0.147

TABLE 8.—(continued).

Date.	Crude sewage.				Coke-bed effluent.		
	Number of fillings per day.	Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as		Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as	
			Nitrite.	Nitrate.		Nitrite.	Nitrate.
1899.							
May 30	Two	3.298	Nil	Nil	2.021	0.007	0.253
31	"	3.958	"	"	2.283	0.070	0.273
June 1	"	3.263	"	"	1.789	0.028	Nil
2	"	2.900	"	"	1.400	0.028	0.128
3	One	2.800	"	"	1.500	0.014	Trace
5	Two	2.727	"	"	1.313	0.070	"
6	"	3.400	0.028	"	1.900	0.140	Nil
7	"	3.900	Nil	"	2.500	0.098	0.045
8	One	2.772	"	"	1.881	0.014	0.157
9	"	3.267	0.028	"	1.683	0.021	0.108
19	Two	3.737	0.014	"	2.020	0.084	0.320
20	"	2.653	Nil	"	1.530	0.070	0.038
21	"	4.388	"	"	2.653	0.014	0.207
22	"	3.500	0.007	Trace	1.900	0.028	0.114
23	"	3.367	Nil	Nil	2.041	Nil	0.083
24	One	2.449	"	"	1.326	0.042	0.039
26	Two	3.438	0.014	"	1.875	Nil	Trace
27	"	2.813	Nil	"	1.458	"	Nil
28	"	2.604	0.007	"	1.458	0.028	0.204
29	"	1.649	Nil	"	0.825	0.007	Trace
30	"	4.845	"	"	2.165	Nil	0.183
July 1	One	2.165	Trace	"	1.134	0.035	0.256
3	Two	1.920	Nil	"	1.010	0.007	Trace
4	"	1.735	"	"	0.512	Trace	0.080
5	"	2.020	"	"	1.111	0.014	Nil
6	"	2.755	"	"	1.224	0.021	0.317
7	One	1.837	"	"	1.021	Trace	0.148
10	Two	2.376	"	"	1.386	Nil	Trace
11	"	3.000	Trace	"	1.700	"	0.055
14	"	2.323	Nil	"	1.414	0.070	0.146
15	One	2.930	Trace	"	1.515	Trace	0.106
17	Two	4.615	"	Trace	2.308	"	0.333
18	"	3.516	Nil	Nil	1.319	Nil	0.134
19	"	2.967	"	"	1.648	"	Nil
20	"	3.696	Trace	"	2.174	Trace	0.083
21	One	2.777	Nil	"	1.555	"	0.068
25	Two	3.152	"	"	1.739	Nil	0.873
31	One	2.222	"	"	0.889	0.070	0.492
Aug. 1	Two	2.889	"	"	1.222	Nil	Nil
2	"	4.667	"	"	2.667	"	0.485
3	"	2.857	"	"	1.758	0.044	Nil
4	"	3.763	"	"	2.473	Trace	0.364
9	"	3.778	"	"	2.111	0.028	Nil
10	"	3.736	"	"	2.088	Trace	0.358
11	"	3.736	"	"	2.527	Nil	Nil
12	One	3.804	"	"	2.069	"	Trace
14	"	2.527	"	"	2.087	"	0.2647
15	Two	3.951	"	"	2.790	"	Nil
16	"	3.493	"	"	1.929	"	0.5045
21	One	4.942	"	"	2.414	"	Nil
22	Two	4.369	"	"	2.896	"	"
23	"	4.045	"	"	1.574	"	"
24	"	4.943	"	"	2.248	"	0.6271
25	"	4.118	"	"	1.882	0.056	0.1740
26	One	3.529	"	"	1.412	Trace	1.1025
28	Two	5.048	"	"	2.041	0.0056	Nil
29	"	5.102	"	"	2.245	Trace	Trace
30	"	3.265	"	"	2.347	Nil	0.5294
31	"	3.939	"	"	1.919	0.035	Nil
Sept. 1	"	3.571	"	"	1.735	Nil	"
2	One	3.300	"	"	1.190	"	0.1765
4	Two	2.525	"	"	1.313	"	Nil
5	"	3.300	"	"	1.100	"	"
6	"	3.030	"	"	1.717	0.014	"
7	"	3.366	"	"	1.735	0.028	0.3770
9	One	2.857	"	"	2.449	Nil	Nil
11	Two	2.857	"	"	1.633	"	"
12	"	4.040	"	"	1.616	0.3860	"
13	"	4.286	"	"	2.245	Nil	"
14	"	4.592	"	"	1.837	"	"
15	"	1.020	"	"	0.918	"	"
16	One	2.200	"	"	1.700	0.2647	0.0112
18	Two	3.700	"	"	1.400	Nil	Nil

TABLE 8.—(continued).

Date.	Crude sewage.				Coke-bed effluent.		
	Number of fillings per day.	Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as		Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as	
			Nitrite.	Nitrate.		Nitrite.	Nitrate.
1899.							
Sept. 19	Two	4.216	Nil	Nil	1.667	Trace	0.0098
20	"	4.257	"	"	1.881	0.2164	Nil
21	"	4.300	"	"	1.600	Nil	Trace
22	"	3.900	"	"	1.700	"	Nil
23	One	3.431	"	"	1.667	0.0916	"
25	Two	2.871	"	"	1.485	Nil	"
26	"	4.608	"	"	1.667	Trace	0.0280
27	"	2.857	"	"	1.099	Nil	Trace
28	"	4.725	"	"	1.868	"	Nil
29	"	2.826	"	"	1.304	Trace	"
Oct. 2	"	2.747	0.0168	"	1.648	0.0350	"
3	"	4.505	Nil	"	1.319	0.0280	Trace
4	"	5.000	"	"	2.127	0.0210	0.3494
5	"	4.176	"	0.1752	1.649	Nil	Trace
6	"	4.222	"	Nil	1.555	"	Nil
7	One	3.279	"	"	0.659	"	"
9	Two	4.945	"	"	1.760	"	"
13	One	4.456	"	"	1.521	"	"
16	"	2.151	"	"	1.182	0.0378	0.2361
23	"	4.545	"	"	1.515	0.3930	Trace

Date.	Number of fillings per day.	CRUDE SEWAGE.				COKE-BED EFFLUENT.			
		Oxygen absorbed from permanganate in 4 hours.		Nitrogen as		Oxygen absorbed from permanganate in 4 hours.		Nitrogen as	
		By the total putrescible matter.	By the dissolved putrescible matter.	Nitrite.	Nitrate.	By the total putrescible matter.	By the dissolved putrescible matter.	Nitrite.	Nitrate.
1899.									
Nov. 7	Two	6.000	2.946	0.0952	Trace	2.321	1.473	0.3780	1.2117
8	"	6.000	4.210	Nil	"	2.936	2.326	0.2100	1.0980
9	"	6.000	3.053	0.0168	0.0573	2.210	1.358	0.1470	0.4011
10	"	6.355	2.917	0.0070	Nil	2.601	1.500	0.0798	Nil
11	One	6.314	2.946	Nil	"	2.321	1.358	0.1470	0.7270
14	Two	6.288	3.814	"	"	1.855	1.855	Nil	Nil
15	"	7.031	3.609	"	"	2.371	1.855	"	"
16	"	6.041	3.442	"	"	2.500	2.396	"	"
17	"	5.051	3.300	"	"	2.062	1.670	"	"
18	One	4.737	3.263	"	"	2.316	2.026	"	0.1763
20	Two	5.625	4.026	"	"	1.562	1.458	0.0393	Trace
21	"	6.459	6.159	"	"	2.917	2.078	Nil	0.0886
22	"	6.296	4.722	"	"	2.315	2.129	"	Trace
23	"	9.074	5.642	"	0.0796	2.129	2.037	"	0.1436
24	"	7.685	4.629	"	Nil	2.407	1.825	"	Nil
25	One	4.537	2.685	"	"	1.388	1.203	"	"
27	Two	9.174	6.055	"	"	3.119	2.752	"	0.0591
28	"	8.718	5.779	"	"	3.846	3.211	"	0.0835
29	"	7.830	4.710	"	"	2.547	1.792	"	0.1743
30	"	7.339	4.312	"	"	2.568	1.926	"	Trace
Dec. 1	"	6.605	3.669	"	"	2.568	1.926	"	"
2	One	6.880	5.229	"	"	1.834	1.642	"	Nil
4	Two	9.174	6.330	"	"	2.110	1.468	"	"
5	"	7.957	4.731	"	"	2.105	1.720	"	"
6	"	8.125	5.834	"	"	2.917	1.979	"	"
7	"	7.579	5.473	"	"	3.579	2.631	"	"
8	"	7.683	4.734	"	"	2.726	2.000	"	"
9	One	3.871	2.903	"	"	2.473	1.496	"	"
12	"	7.938	5.361	"	Trace	2.165	1.236	0.028	0.3481
13	Two	7.526	5.051	"	Nil	2.887	2.062	Nil	Trace
14	"	6.354	4.583	"	"	2.500	1.536	"	Nil
15	One	6.956	5.217	"	"	2.826	2.282	"	"
16	"	6.210	5.369	"	"	2.105	1.894	"	"
18	Two	4.376	3.541	"	"	2.601	1.771	"	"
19	One	9.592	6.938	0.007	Trace	5.102	2.347	0.091	0.2383
20	"	9.278	6.701	Nil	Nil	4.020	3.299	Nil	Nil
21	"	5.307	3.775	"	Trace	2.347	1.836	"	0.1179
22	"	14.949	8.383	"	Nil	4.545	3.434	"	Trace

AVERAGES.

Feb. 27—March 25		3.399	0.0019	0.0000		1.587	0.0189	0.0486
March 27—Oct. 23		3.386	0.0023	0.0016		1.774	0.0274	0.1163
Nov. 7—Dec. 22	7.077	4.633	0.0034	0.0037	2.624	1.968	0.0295	0.1282
March 27—Dec. 22	7.077	3.650	0.0026	0.0020	2.624	1.815	0.0279	0.1188
Feb. 27—Dec. 22	7.077	3.622	0.0025	0.0018	2.624	1.789	0.0269	0.1108

TABLE 9.—DETAILS OF THE ANALYTICAL RESULTS OBTAINED FROM THE TREATMENT OF CRUDE SEWAGE BY RAPID SEDIMENTATION FOLLOWED BY INTERMITTENT TREATMENT IN A COKE-BED.

Date.	Daily average rate of flow of the sewage through the channels. Feet per minute.	Average daily samples of the sewage subjected to sedimentation, collected during 24 hours' flow.				Average samples of the portion of sedimented sewage subjected to coke-bed treatment.	
		Oxygen absorbed from permanganate in four hours.					
		By the total oxidisable matter in the sewage.	By the dissolved oxidisable matter in the sewage.	By the total oxidisable matter in sewage effluent after sedimentation.	By the dissolved oxidisable matter in the sewage effluent after sedimentation.	By the dissolved oxidisable matter in the sewage effluent after sedimentation and before coke-bed treatment.	By the dissolved oxidisable matter in the effluent from the coke-bed.
1899.							
Dec. 24 ...	10.6	6.735	4.082	5.204	3.877	...	...
25 ...	9.0	6.392	4.227	5.051	4.020	4.316	2.830
26 ...	9.4	6.916	4.299	6.074	4.392	3.720	2.081
27 ...	8.3	7.245	5.102	6.530	5.204	3.855	2.081
28 ...	11.5	8.061	5.714	6.735	5.612	4.400	2.000
29 ...	12.8	8.989	5.555	7.171	5.454	3.600	1.700
30 ...	5.8	7.938	3.093	6.146	3.750	3.500	1.660
31 ...	5.2	7.187	4.270	5.876	3.195	...	...
1900.							
Jan. 1 ...	9.9	7.083	4.061	5.416	4.166	2.963	1.394
2 ...	7.1	6.562	3.646	5.833	3.750	3.708	1.650
3 ...	6.3	7.745	4.705	6.372	4.705	5.106	2.172
4 ...	4.3	6.019	3.883	4.174	3.689	4.480	2.059
5 ...	4.8	6.956	5.326	6.521	5.000	4.736	2.020
6 ...	5.1	6.333	3.888	5.333	4.000	3.826	1.913
7 ...	5.9	6.333	3.444	5.444	3.777	...	...
8 ...	6.9	6.593	4.615	6.252	4.615	3.700	1.500
9 ...	7.3	7.234	4.489	6.489	4.042	2.800	1.300
10 ...	6.5	7.174	5.109	6.087	5.217	3.333	1.616
11 ...	6.3	6.739	4.782	6.087	5.000	3.737	1.212
12 ...	5.6	7.766	5.000	6.490	5.319	4.217	1.992
13 ...	5.8	6.989	4.516	5.698	4.622	4.602	2.043
Average percentage purification		7.4 ...	7.095 ...	4.467 ...	5.952 16.1 0.4	4.448 12.2	1.846 58.7 on the crude sewage. 52.9 on the sedimented sewage.

DIVISION II.—BACTERIOLOGICAL.

BY

A. C. HOUSTON, M.B., D.Sc.

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DIVISION II.—BACTERIOLOGICAL.

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DIVISION II.—BACTERIOLOGICAL.

I.—SUMMARY OF THE CONTENTS OF PREVIOUS REPORTS.

1.—SUMMARY OF THE CONTENTS OF THE FIRST REPORT.*

In this Report a description of some of the methods used in the bacteriological examination of sewage was given, and the results of the bacteriological examination of nine samples of Barking and six samples of Crossness crude sewage as regards the total number of bacteria, the number of spores of bacteria and the number of liquefying bacteria, and as regards the species of micro-organisms present were expressed in the form of a table.

Fourteen micro-photographs illustrating the work accompanied the Report.

The chief results obtained may be stated as follows—

1 Description of the sample of crude sewage.	2 Total number of bacteria in 1 c.c.	3 Number of spores of bacteria in 1 c.c.	4 Number of liquefying bacteria in 1 c.c.	5 Number of <i>B. coli</i> (or closely allied forms) in 1 c.c.	6 No. of spores of <i>B. enteritidis sporogenes</i> (Klein) in 1 c.c.
Barking— Crude sewage (9 samples)	3,899,259	332 (excluding extreme results).	430,750	Usually more than 100,000	From 10 to 1,000 (usually more than 100).
Crossness— Crude sewage (6 samples)	3,526,667	365 (excluding extreme results).	400,000	Usually more than 100,000	From 10 to 1,000 (usually more than 100).

Although prior to the publication of this Report there were numerous records of the total number of micro-organisms in raw sewage, it is believed that there were few, if any, data dealing with the systematic examination of samples of crude sewage as regards the estimation of the number of aerobic bacteria present in the form of spores, the number of microbes causing liquefaction of gelatine, the number of *B. coli* and spores of the pathogenic *B. enteritidis sporogenes*.

Such records were considered to be highly important as preparatory to a study of the effluents from biological coke-beds. Moreover these records have a special interest from the point of view of the bacterioscopic examination of drinking water.† Thus pure water rarely contains more than 100-200 bacteria per c.c. and very few, if any, spores in a similar quantity. As regards liquefying bacteria, these are present in considerable numbers even in very pure waters, but they are for the most part different in sort from those found in sewage.§ *B. coli* is not present, or only in small numbers in water free from any objectionable pollution, and the spores of *B. enteritidis sporogenes* are absent from as much, it may be, as 100 to 500 c.c. of a pure water.

It is worthy of note that relatively to the total number of microbes, the number of spores of bacteria is much greater in surface soils‡ than in sewage or in water. Further, that pure soils do not contain the spores of *B. enteritidis sporogenes* even in as much as 10 mgrms. of the soil, whereas impure soils may contain 10,000 per gramme. Lastly, *B. coli* appears to be absent from pure virgin soils and present, it may be, in considerable numbers in soils recently polluted.

Although the estimation of the total number of micro-organisms, the number of spores of bacteria, and the number of liquefying germs was considered not unimportant, chief stress is to be laid on the enumeration of *B. coli* and spores of *B. enteritidis sporogenes*.

B. coli is an organism characteristic of the intestinal discharge of animals, and especially abundant therein. Moreover, it may be pathogenic, although it can hardly be considered as a pathogenic microbe under ordinary conditions and in the usual acceptance of the term. Certainly, however, its presence serves as an index of the possible presence of other and perhaps dangerous bacteria of recent animal outcome.

* The Report contained a record of the work done from February 23rd to May 9th, 1898. Filtration of sewage. Report on the bacteriological examination of London crude sewage. First Report. (P. S. King and Son, 2 and 4, Great Smith-street, Westminster, S.W.)

† It is remarkable that notwithstanding the fact that sewage is the most common and most dangerous source of the pollution of drinking waters so little is known of the bacterial composition of sewage.

§ For example: in the Second Report a large number of experiments are given showing that in sewage and in the effluents from bacterial beds a gas-forming rapidly liquefying microbe described as "*sewage proteus*" is present in numbers usually exceeding 100,000 per c.c. This micro-organism was sometimes found to be very virulent.

‡ Report of the Medical Officer, Local Government Board, 1897-8.

As regards *B. enteritidis sporogenes*, this anaërobe is not only typical of excremental matters, but its cultures are extremely virulent to animals, and Dr. Klein's researches point to its being causally related to certain cases of acute diarrhœa in the human subject.

There was a manifest advantage in choosing two micro-organisms—one an aërobe and the other an anaërobe, with the object of counting their numbers first in the crude sewage and afterwards in the effluent from bacterial coke-beds and *B. coli* and *B. enteritidis sporogenes* seemed to be microbes peculiarly well-fitted for the purpose.

2.—SUMMARY OF THE CONTENTS OF THE SECOND REPORT.*

The Report is divided into a chemical and bacteriological division.

DIVISION I.—CHEMICAL.

Here Dr. Clowes deals with the chemical and practical side of the question under (1) objects of the coke-bed experiments; (2) general results obtained; (3) general conclusions; (4) advantages of bacterial over chemical treatment; (5) construction and details of the coke-beds; (6) methods of working the beds and their condition at the time of writing the Report; (7) history of each coke-bed; (8) experimental proof of the aëration of the coke-beds; (9) variation in the condition of the raw sewage, and its effect upon the effluent; (10) comparative purity of clear sewage, bacterial effluent and chemical effluent.

DIVISION II.—BACTERIOLOGICAL.

It is this division of the Report which it is now proposed to summarise.

It will be remembered that the First Report dealt with a period extending from the end of February to the beginning of May, 1898, and with the bacteriological examination of the raw sewage only—the bacterial coke-beds being at the period referred to in course of construction. The Second Report carried the enquiry a stage further, since it dealt with the bacteriological examination of the effluents from the bacterial coke-beds as well as of the raw sewage. The main portion of the Report treated of a period extending from May 9th to August 9th, 1898. But in the Addenda A, B, C, D, E, further bacteriological records were given, bringing the work up to the end of that year. The following summary takes note of the whole of the above period. As the descriptive matter in the Second Report dealt only with the period from May 9th to August 9th, 1898, and as the records contained in the Addenda A, B, C, D, E covered a large interval of time (August 9th to December 31st, 1898) it will be necessary to collect all the figures together and to summarise the results as a whole.

It is of advantage first to give the chief results† obtained in the form of tables and then to make certain comments thereon.

But before doing so, it is desirable to state in a few sentences what the contents of the Second Report were. It will, of course, be impossible to summarise all the different sections, and for information under the headings not dealt with in the following pages reference must be made to the Report itself.

CONTENTS OF SECOND REPORT.

A.—INTRODUCTION.

B.—SUMMARY OF CONTENTS OF FIRST REPORT

I.—THE BIOLOGICAL TREATMENT OF SEWAGE.

II.—GENERAL RESULTS OBTAINED (MAY 9TH TO AUGUST 9TH, 1898).

III.—SUMMARY OF RESULTS SHEWN IN TABLE I.—1. Total number of Bacteria. 2. Number of Spores of Bacteria. 3. Number of Liquefying Bacteria. 4. Species of Micro-organisms. (a) *B. Enteritidis Sporogenes* (Klein). (b) *B. Coli Communis*. (c) Other species of Bacteria.

IV.—TABLES AND DIAGRAMS DEALING WITH THE RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE CRUDE SEWAGE, OF THE EFFLUENTS FROM THE COKE-BEDS; AND OF THE EFFLUENT FROM THE CHEMICAL PRECIPITATION WORKS, AND OF SAMPLES OF THAMES WATER.

V.—DESCRIPTION OF SOME OF THE BACTERIA FOUND IN THE CRUDE SEWAGE, AND IN THE EFFLUENTS FROM THE COKE-BEDS. 1. *B. Coli Communis*. 2. *B. Mesentericus*. (a) *B. Mesentericus E.* (b) *B. Mesentericus I.* 3. *Sewage Proteus*. 4. *B. Frondosus*. 5. *B. Fusiformis*. 6. *B. Subtilissimus*. 7. *B. Subtilis*. *Sewage variety A.* *Sewage variety B.* 8. *B. Membraneus Patulus*. 9. *B. Capillareus*.

VI.—DESCRIPTION OF MICRO-PHOTOGRAPHS AND DIAGRAMMATIC DRAWINGS ACCOMPANYING THE REPORT.

VII.—ADDENDA A, B, C, D, E.—FURTHER BACTERIOLOGICAL RECORDS (AUGUST 9TH TO DECEMBER 31ST, 1898.)

* Bacterial treatment of crude sewage (Second Report.) Experimental intermittent treatment of London crude sewage in the coke-beds at Crossness. (P. S. King and Son, 2 and 4, Great Smith-street, Westminster, S.W.)

† The figures are not *strictly* comparable with those given in the First Report, because in order to obtain corresponding samples of the raw sewage and of the effluents from the coke-beds, a somewhat longer interval elapsed between the time of the collection of the samples of crude sewage and their subsequent examination than was the case during the earlier portion of the enquiry.

In the following pages the chief results as regards (1) total number of bacteria, (2) number of spores of bacteria, (3) number of liquefying bacteria, (4) number of *B. coli*, and (5) number of spores of *B. enteritidis sporogenes* are tabulated and summarised. Both the records contained in the text of the Second Report and those given in the Addenda A, B, C, D, E, are here dealt with. The necessity of collecting these figures together, and making brief comments thereon, will make the summary less concise than it would otherwise have been.

(a) TOTAL NUMBER OF BACTERIA IN 1 c.c.

Date.		Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke-bed.
1898.					
Second Report, page 21 Addendum A.	May 11	3,930,000	4,800,000	...	...
	18	3,670,000	4,100,000	...	...
	25	6,400,000	6,100,000	...	...
	June 9	6,500,000	1,200,000	...	...
	15	4,000,000	5,300,000	...	...
	22	9,100,000	3,000,000	...	...
	July 20	12,800,000	9,200,000	...	...
	27	7,200,000	...	6,600,000	...
	August 4	4,200,000	1,800,000	...	...
	9	3,600,000	...	1,700,000	...
	19	5,800,000	3,400,000	...	...
	24	4,100,000	...	5,700,000	...
	September 14	8,000,000	3,400,000	...	...
	21	8,600,000	...	7,200,000	...
	28	7,500,000	7,500,000	...	...
	October 5	10,500,000	...	8,000,000	...
	12	4,000,000	4,200,000	...	...
	21	8,000,000	...	15,800,000	...
	26	5,200,000	...	...	3,100,000
	November 9	7,800,000	8,800,000	...	...
	16	5,800,000	...	5,300,000	...
	23	8,600,000	...	...	4,500,000
	30	13,500,000	5,400,000	...	...
	December 7	5,600,000	...	4,000,000	...
	14	19,500,000	...	...	5,300,000
	21	7,400,000	6,300,000	...	...
Averages ...		7,357,692 (26 samples)	4,966,666 (15 samples)	6,787,500 (8 samples)	4,300,000 (3 samples)
Percentage reduction (as compared with the raw sewage).			32 per cent.	7 per cent.	41 per cent.
Average number of bacteria in the raw sewage when the samples were comparative with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds.		6,973,333 (15 samples corresponding to 4 ft. samples.)	4,966,666 28 per cent. reduction.	{ 6,787,500 slight increase.	{ 4,300,000 61 per cent. reduction.
		6,675,000 (8 samples corresponding to 6 ft. primary samples.)			
		11,100,000 (3 samples corresponding to 6 ft. secondary samples.)			

The table shows that the total number of bacteria in the crude sewage (26 samples), the effluent from the 4-foot coke-bed (15 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (3 samples) averaged 7,357,692, 4,966,666, 6,787,500, and 4,300,000 per c.c. respectively. The percentage reduction of bacteria in the effluents being 32, 7, and 41. The average number of bacteria in the 15 samples of crude sewage corresponding to the 4-foot coke-bed effluents was 6,973,333. In the eight samples corresponding to the 6-foot primary coke-bed effluents the average was 6,675,000. Lastly, the three samples of crude sewage corresponding to the 6-foot secondary coke-bed effluents yielded on an average 11,100,000 bacteria per c.c. Calculated from these figures, the percentage reduction of bacteria was 28 as regards the 4-foot coke-bed effluents; no reduction, but a slight increase as regards the 6-foot primary coke-bed effluents, and 61 per cent. in respect of the 6-foot secondary coke-bed effluents.

As a rule a rise or fall above or below the mean in the number of bacteria in the crude sewage was associated with a similar increase or decrease of microbes in the corresponding effluents. Thus, as regards the crude sewage and 4-foot coke-bed effluents, there was a correspondence in this respect on 11 occasions out of 15; and as regards the raw sewage and 6-foot primary coke-bed effluents this correspondence was observed in all the eight samples. The records

of the examination of the 6-foot secondary coke-bed effluents are too few in number to allow of useful conclusions being drawn, but here also the same agreement occurred. The above must not be taken as meaning that the percentage deviation from the mean showed any parallelism as regards the crude sewage and corresponding effluents.

So far as a diminution in the number of bacteria may be taken as an indication of purification, it must be admitted that the above results are not satisfactory. And if they are unfavourable from the point of view of percentage reduction effected, still less are they favourable when judged by the actual state of the effluents.

It is noteworthy that the reduction in the number of bacteria was much greater in the effluent from the 4-foot coke-bed than in the effluent from the 6-foot primary coke-bed, and was nearly as much as in the effluent from the 6-foot secondary coke-bed.

Possibly the records as regards the 6-foot primary coke-bed indicate a retrograde change.

Since the coke-beds are intended to encourage the life processes of bacteria it might be urged that an increase, or, at all events, the absence of a marked decrease in the number of bacteria in the effluents is of little importance. Further, that it may even be a desirable thing that an effluent only partially purified should carry with it the bacteria which have been engaged in the work of purification in order to complete their work. There may be truth in these contentions, but as experience has shown that the bacterial beds which yield the best chemical results yield also the best results bacteriologically, and as river water already contains all the necessary germs of putrefaction and nitrification, it would seem to be undesirable to discharge with an effluent countless germs of a kind to be associated with the recent evacuations of animals. Moreover, some of these micro-organisms are pathogenic, and doubtless many of them, although perhaps slowly working in the direction of purification, are, in a sense, intruders, since the work could probably be more efficiently carried out in their absence by other and unobjectionable bacteria.

As regards the value to be assigned to the estimation of the total number of microbes, it may be said that the greater the number of micro-organisms in a liquid containing a mixed bacterial flora the more likely is it that some of them are of a harmful nature. But further than this, the prolonged investigations carried out in this enquiry as regards the species of microbes and their relative numbers give to the above figures a special and peculiar value. For while there is no fixed proportion between the total number of bacteria, and, for example, the number of proteus-like germs, of *B. coli* and of spores of *B. enteritidis sporogenes*, it has been abundantly shown that *with a sample of effluent or raw sewage, containing an average number of microbes, say three to nine millions per c.c., the number of "sewage proteus" of B. coli and of spores of B. enteritidis sporogenes is likely to be not less than 100,000; at least 100,000, and usually more than 100 respectively. Further, that more than one-tenth of the bacteria are likely to be "liquefiers," and only about one in 20,000 present as spores (aërobes).*

As the bacterial composition of London crude sewage does not differ widely from the raw sewage of most other towns, it is believed that these records have a wide range of usefulness. At the risk of repetition it may be pointed out that their bearing on the bacterioscopic examination of potable waters is very important.

(b) NUMBER OF SPORES OF AËROBIC BACTERIA IN 1 C.C.

Date.		Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke-bed.
Second Report, Addendum C.1 Second Report, page 22.	1898				
	May 11	460	260	...	...
	18	300	140	...	...
	25	370	380	...	...
	June 9	560	230	...	...
	15	180	300	...	...
	22	310	60	...	...
	July 20	400	430	...	...
	27	870	...	480	...
	August 4	280	220	...	...
	9	340	...	300	...
	19	220	200	...	...
	24	170	...	180	...
	September 14	*	*	...	...
	21	250	...	190	...
	28	260	490	...	...
	October 5	200	...	130	...
	12	320	240	...	...
	21	340	...	420	...
	26	200	...	...	220
	November 9	150	140	...	...
	16	240	...	180	...
	23	510	...	...	320
	30	440	310	...	...
	December 7	70	...	170	...
	14	800	...	...	420
	21	270	140	...	...
	Averages ...	340	252	256	320
		(25 samples.)	(14 samples.)	(8 samples.)	(3 samples.)
Percentage reduction (as compared with the raw sewage).			25 per cent.	24 per cent.	5 per cent.

* The rapid liquefaction of the gelatine prevented accurate counting.

(b) NUMBER OF SPORES OF AEROBIC BACTERIA IN 1 C.C.—*continued.*

Date.	Crossness crude sewage.	Effluent from 4-ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke-bed.
Average number of spores of bacteria in the raw sewage where the samples were compara- tive with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds.	322 (14 samples, cor- responding to 4ft. samples). 310 (8 samples corres- ponding to 6 ft. primary samples) 503 (3 samples cor- responding to 6 ft. secondary samples).	252 21 per cent. reduction.	256 17 per cent. reduction. ...	320 36 per cent. reduction.

The table shows that the number of spores of bacteria in the crude sewage (25 samples), the effluent from the 4-foot coke-bed (14 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (3 samples), averaged 340, 252, 256, and 320 per c.c. respectively. The percentage reduction in the effluents as compared with the crude sewage being 25, 24, and 5. The average number of spores in the 14 samples of crude sewage corresponding to the 4-foot coke-bed effluents was 322; in the 8 samples corresponding to the 6-foot primary coke-bed effluents, 310; and in the 3 samples corresponding to the 6-foot secondary coke-bed effluent the average was 503. Calculated from these figures the percentage reduction in the number of spores of bacteria was 21 as regards the 4-foot coke-bed effluents, 17 as regards the 6-foot primary coke-bed effluents, and 36 in respect of the 6-foot secondary coke-bed effluents.

Usually a rise or fall above or below the mean in the number of spores of bacteria in the raw sewage was associated with a similar increase or decrease in the number in the corresponding effluents. Thus as regards the crude sewage and 4-foot coke-bed effluents there was in this respect a relation between the two in 11 out of 14 samples; and the raw sewage and 6-foot primary coke-bed effluents showed a similar correspondence in six out of eight comparative samples. The same relationship was noticed with reference to the 6-foot secondary coke-bed effluents, but here only three samples were examined.

So far as may be judged from a rise or fall above or below the mean the figures show no distinct parallelism between the total number of bacteria and the number of spores of bacteria in the case either of the crude sewage or of the effluents from the 6-foot primary coke-bed. But as regards the 4-foot coke-bed effluents there is evidence of a distinct relation.

It will be understood that in the above remarks, when mention is made of a relationship, it does not imply a parallelism as regards *percentage* deviation from the mean.

In the Second Report it was shewn that the percentage reduction in the number of bacteria and the number of spores of bacteria in the 4-foot coke-bed effluent as compared with the crude sewage was 27.7 and 38 respectively. Here and when dealing with a larger number of records, i.e., including those given in Addenda A and C, as well as those contained in the body of the Report, the figures are slightly different, being in the first case 32 per cent. and in the second 25 per cent.

It is difficult to gauge the exact significance of the number of spores of aerobic bacteria and the number relative to the total number of bacteria. Spores of bacteria are peculiarly resistant to unfavourable physical conditions; fortunately, however, the majority, at all events, of the spores of *aerobic* micro-organisms found in sewage belong to species which are believed to be harmless.

Although the actual number of spores in sewage is large, the number relative to the total number of bacteria is very small. Thus in the 26 samples above recorded for every microbe present in the spore-form there were present over 21,000 in the vegetative-form. And this result is not in all probability to be traced solely to the comparative infrequency of bacteria in sewage *capable* of forming spores, but also to the active and continued multiplication of the micro-organisms in the presence of an abundance of suitable pabulum. In the case of effluents from bacterial beds it is conceivable that a smaller reduction in the number of spores of bacteria as compared with the reduction in the total number of bacteria, or an actual increase in the number of spores in the effluent as compared with the crude sewage might be a good rather than a bad sign as indicating that the organic pabulum was becoming exhausted and the conditions for bacterial life so unfavourable as to lead the microbes to form spores so as to escape extinction.

In my reports to the Local Government Board on the bacteriological examination of soils I have shewn that in surface soils not only is the number of spores very large, but also that they are very numerous in relation to the total number of bacteria. Thus in soils it is common to find the ratio between the number of spores and number of bacteria—1:2; 1:3; 1:4; 1:5; 1:6; 1:7; 1:8; 1:9 and 1:10. Sometimes the ratio may be 1:20; 1:30; 1:40, or lower, but here the

cause is usually to be found in the presence of an excess of moisture and also of organic pabulum. Although the number of bacteria capable of forming spores in soils is peculiarly great, it is probable that the majority of these form spores only when there is a deficiency in the amount of liquid organic pabulum and when the physical conditions are unfavourable.

It is, perhaps, permissible to hazard the conjecture that an increase (actual or relative) in the number of spores of bacteria in effluents from bacterial beds is possibly a favourable sign. Yet surmises such as the above are best received with caution, especially as they are to some extent founded on a comparison between a liquid (sewage) in the one case and a solid (soil) in the other.

Certainly, however, it is a point worth noting that in soils the ratio of spores to bacteria is commonly more than 1: 10 and in sewage less than 1: 10,000. Waters, it may be added, differ rather widely in this respect, but they always approximate much more closely to the ratio found in sewage than to that found in soil.

(c) NUMBER OF BACTERIA CAUSING LIQUEFACTION OF GELATINE IN 1 c.c.

DATE.			Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft secondary coke-bed.
1898.						
Second Report, Addendum B. { Second Report, page 23	May	11	400,000	1,300,000	...	...
		18	100,000	700,000	...	...
		25	900,000	700,000	...	...
	June	9	1,400,000	200,000	...	...
		15	800,000	1,100,000	...	...
		22	900,000	600,000	...	...
	July	20	1,700,000	1,000,000	...	...
		27	900,000	...	300,000	...
		4	400,000	500,000	...	...
	August	9	1,100,000	...	200,000	...
		19	600,000	400,000	...	...
		24	600,000	...	1,100,000	...
	September	14	700,000	700,000	...	...
		21	1,200,000	...	1,100,000	...
		28	1,200,000	1,200,000	...	...
	October	5	2,400,000	...	600,000	...
		12	700,000	1,200,000	...	...
		21	1,000,000	...	1,000,000	...
	November	26	700,000	...	...	500,000
		9	1,900,000	1,400,000	...	...
		16	1,600,000	...	1,500,000	...
	December	23	900,000	...	...	400,000
		30	900,000	500,000	...	...
		7	1,400,000	...	900,000	...
		14	1,400,000	...	...	1,600,000
		21	2,200,000	600,000	...	...
	Averages... ..		1,076,923 (26 samples)	806,666 (15 samples)	837,500 (8 samples)	833,333 (3 samples)
Percentage reduction (as compared with the raw sewage)			25 per cent.	22 per cent.	22 per cent.	
Average number of liquefying bacteria in the raw sewage where the samples were comparative with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds.	{ 986,666 (15 samples corresponding to 4 ft. samples)		806,666 18 per cent. reduction	{ 837,500 34 per cent. reduction	{ 833,333 16 per cent. reduction	
	{ 1,275,000 (8 samples corresponding to 6 ft. primary samples)					
	{ 1,000,000 (3 samples corresponding to 6 ft. secondary samples)		...	...		
			...	...		

The table shows that the number of liquefying bacteria in the crude sewage (26 samples), the effluent from the 4-foot coke-bed (15 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (3 samples) averaged 1,076,923, 806,666, 837,500, and 833,333 per c.c. respectively. The percentage reduction in the number of liquefying bacteria in the effluents being respectively 25, 22, and 22. The average number of liquefying bacteria in the 15 samples of crude sewage corresponding to the 4-foot coke-bed effluents was 986,666. In the 8 samples corresponding to the 6-foot primary coke-bed effluents

the average was 1,275,000, and in the 3 samples corresponding to the 6-foot secondary coke-bed effluents 1,000,000. Calculated from these figures the percentage reduction of liquefying bacteria was 18 as regards the 4-foot coke-bed effluents, 34 in respect of the 6-foot primary coke-bed effluents, and 16 as regards the 6-foot secondary coke-bed effluents.

Usually a rise or fall above or below the mean in the number of liquefying bacteria in the crude sewage was associated with a similar increase or decrease in the number in the corresponding effluents. Thus as regards the crude sewage and 4-foot coke-bed effluents, in 10 out of the 15 experiments there was a correspondence, and in the case of the 6-foot primary coke-bed effluents, 4 out of the 8 samples corresponding to the crude sewage showed a similar relationship. Only 3 samples of the effluent from the 6-foot secondary coke-bed were examined; these in each case were related to the raw sewage in the above sense.

So far as may be judged from a rise or fall above or below the mean, the figures show a certain parallelism between the total number of bacteria in the crude sewage and the number of liquefying bacteria, and lastly between the number of spores and liquefiers.

As regards the 4-foot coke-bed effluents there is evidence of a distinct relation between the total number of bacteria and spores of bacteria, the total number of bacteria and the number of liquefying bacteria, but little or none between the number of spores and number of liquefiers.

With respect to the 6-foot primary coke-bed effluents there is no definite correspondence between the total number of bacteria and either the number of spores of bacteria or the number of liquefiers; and the spores and liquefiers show, if anything, an inverse relation.

It is to be noted that the number of liquefying bacteria was less in the effluents from the 4-foot coke-bed than in the effluents either from the 6-foot primary or 6-foot secondary coke-beds.

The exact value to be placed on the determination of the number of liquefying bacteria is difficult to judge of. At one time it was thought that the greater the number of liquefying bacteria in a water the more dangerous was the nature of the contamination, and the more unfit the water was for domestic use. But as many objectionable bacteria (e.g., *B. coli*) do not liquefy gelatine and many pure waters are rich in liquefying microbes of a harmless nature, this test fell into comparative disfavour. When, however, the character of the liquefying bacteria in the substance under examination is taken into consideration, the position of things is somewhat altered. Thus in 14 samples of crude sewage and effluents there were present at least 100,000 gas-forming "*sewage proteus*"* per c.c. So that it may safely be said that at least one-tenth of the numerous liquefying bacteria in sewage are proteus-like in character. And as some of the *strains* of this "*sewage proteus*" isolated from the raw sewage and the effluents were found to be very virulent, it may be added that crude sewage and effluents from bacterial coke-beds are not only rich in liquefying bacteria, but that they contain liquefying germs in great abundance which are very objectionable in kind.

In conclusion it is worthy of note that the ratios of spores and of liquefiers to the total number of bacteria in the crude sewage and effluents are as follows—

Crude sewage (26 samples)—Ratio of spores (aërobes) to total number of bacteria	...	...	...	= 1 : 21,640
4-foot coke-bed effluent (15 samples)—Ratio of spores (aërobes) to total number of bacteria	...	...	...	= 1 : 19,709
6-foot primary coke-bed effluent (8 samples)—Ratio of spores (aërobes) to total number of bacteria	...	...	...	= 1 : 26,513
6-foot secondary coke-bed effluent (3 samples)—Ratio of spores (aërobes) to total number of bacteria	...	...	...	= 1 : 13,436
Crude sewage (26 samples)—Ratio of liquefiers to total number of bacteria	...	...	...	= 1 : 6·8
4-foot coke-bed effluent (15 samples)—Ratio of liquefiers to total number of bacteria	...	...	...	= 1 : 6·1
6-foot primary coke-bed effluent (8 samples)—Ratio of liquefiers to total number of bacteria	...	...	...	= 1 : 8·1
6-foot secondary coke-bed effluent (3 samples)—Ratio of liquefiers to total number of bacteria	...	...	...	= 1 : 5·1

These results would seem to indicate that the result of the bacterial treatment of the raw sewage in the coke-beds was to effect an increase in the number of spores and of liquefiers relative to the total number of micro-organisms in the case of the 4-foot and 6-foot secondary beds and to bring about a decrease in the number of spores and liquefiers relative to the total number in the case of the 6-foot primary coke-bed. In the Second Report it was stated that the percentage reduction of spores was greater than the reduction of the total number of micro-organisms in the 4-foot coke-bed effluent as compared with the crude sewage. The figures, however, dealt only with the period extending from May 9th to August 9th, whereas the above records include as well those given in Addenda to the Second Report—i.e., the results obtained between August 9th to December 31st, 1898.

* This micro-organism is fully described in Section V., Division II., of Second Report.

(d) NUMBER OF *B. COLI* OR CLOSELY ALLIED FORMS IN 1 C.C.

Date.		Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. (primary) coke-bed.	Effluent from 6 ft. (secondary) coke-bed.
Second Report, Addendum D. Second Report, page 26	1898.				
	May 11	None in 0·00001 c.c.	200,000	...	...
	18	300,000	200,000	...	...
	25	1,500,000	700,000	...	...
	June 9	200,000	100,000	...	...
	15	300,000	600,000	...	...
	22	300,000	300,000	...	...
	July 20	300,000	300,000	...	...
	27	500,000	...	600,000	...
	August 4	200,000	300,000	...	...
	9	1,000,000	...	200,000	...
	19	100,000	None in 0·00001 c.c.	...	...
	24	300,000	...	400,000	...
	September 14	600,000	400,000	...	...
	21	1,600,000	...	700,000	...
	28	1,000,000	900,000	...	...
	October 5	1,200,000	...	1,300,000	...
	12	800,000	500,000	...	...
	21	800,000	...	800,000	...
	26	None in 0·00001 c.c.	...	...	None in 0·00001 c.c.
	November 9	400,000	400,000	...	...
	16	300,000	...	500,000	...
	23	600,000	...	...	100,000
	30	600,000	200,000	...	...
	December 7	400,000	...	200,000	...
	14	400,000	...	...	100,000
	21	500,000	600,000	...	...
Averages... (in round numbers)		600,000 (24 samples)	400,000 (14 samples)	600,000 (8 samples)	100,000 (2 samples)
Percentage reduction with the raw		sewage.	33 per cent.	No reduction.	83 per cent.
Average number of <i>B. coli</i> in the raw sewage where the sample corresponded with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke- bed.		538,000 (13 samples cor- responding to 4 ft. samples.)	400,000 25 per cent. reduction.	{ 600,000 21 per cent. reduction.	{ 100,000 80 per cent. reduction.
		762,000 (8 samples cor- responding to 6 ft. primary samples.)			
		500,000 (2 samples cor- responding to 6 ft. secondary samples.)			

The table shows that the number of *B. coli* in the crude sewage (24 samples), the effluent from the 4-foot coke-bed (14 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (2 samples) averaged 600,000, 400,000, 600,000 and 100,000 per c.c. respectively. The percentage reduction in the effluents as compared with the crude sewage being 33, no reduction, and 83. The average number of *B. coli* in the 13 samples of crude sewage corresponding to the 4-foot coke-bed effluent was 538,000; in the 8 samples corresponding to the 6-foot primary coke-bed effluents 762,000; and in the 2 samples corresponding to the 6-foot secondary coke-bed effluents the average was 500,000. Based on these figures the percentage reduction in the number of *B. coli* was 25 as regards the 4-foot coke-bed effluents, 21 as regards the 6-foot primary coke-bed effluents, and 80 in respect of the 6-foot secondary coke-bed effluents.

Usually a rise or fall above or below the mean in the number of *B. coli* in the crude sewage was associated with a similar increase or decrease in the number in the corresponding effluents. Thus as regards the crude sewage and 4-foot coke-bed effluents there was in this respect a correspondence between the two in 10 out of 12 samples; and the raw sewage and 6-foot primary coke-bed effluents showed a similar relation in 6 out of the 7 comparative samples. The records as regards the 6-foot secondary coke-bed effluents are too few in number to warrant a comparison being made.

So far as may be judged from a rise or fall above or below the mean the figures show a certain parallelism between the number of *B. coli* and the total number of bacteria both in the crude sewage and in the effluents from the 4-foot and 6-foot primary coke-beds. The records as regards the 6-foot secondary coke-bed are too few to allow of useful conclusions being drawn.

It is to be noted that the average number of *B. coli* in the 6-foot primary coke-bed effluent

was greater than the number in the 4-foot coke-bed effluent, and, indeed, showed no difference from the raw sewage in this respect.

The ratio of the number of *B. coli* to the total number of bacteria in the crude sewage and in the effluents is approximately as follows—

Crude sewage (26 samples)—Ratio of *B. coli* to total number of bacteria = 1 : 12

4-foot coke-bed effluent (15 samples)—Ratio of *B. coli* to total number of bacteria ... = 1 : 12

6-foot primary coke-bed effluent (8 samples)—Ratio of *B. coli* to total number of bacteria ... = 1 : 11

6-foot secondary coke-bed effluent (3 samples)—Ratio of *B. coli* to total number of bacteria ... = 1 : 43

These results would seem to indicate that the result of the bacterial treatment of the raw sewage in the coke-beds was to effect no material alteration in the number of *B. coli* relative to the total number of bacteria in the case of the 4-foot and 6-foot primary coke-beds and to bring about a decrease in the case of the 6-foot secondary coke-bed. In the latter case, however, only 3 samples were examined.

(e) NUMBER OF SPORES OF *B. ENTERITIDIS* *SPOROGENES* IN 1 C.C.

Date.	Crossness crude sewage.	Effluent from 4-ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. coke-bed again passed through the laboratory vessel at Crossness.	Effluent from 6 ft. secondary coke-bed.
1898.					
Second Report, pages 24 and 25.	May 11	at least 10 but less than 100	at least 100 but less than 1,000		
	18	at least 1,000 ...	at least 100 but less than 1,000		
	25	at least 100 but less than 1,000	at least 1,000		
	June 9	at least 100 ...	at least 100		
	15	at least 10 ...	at least 10		
	22	at least 1,000 ...	at least 10 but less than 100		
	July 6	at least 10 but less than 100	...	at least 10 but less than 100	
	20	at least 100 but less than 1,000	at least 100 but less than 1,000	at least 100	
	27	at least 100 ...	at least 100 but less than 1,000	at least 10 but less than 100	
	Aug. 4	at least 100 ...	at least 100 ...	at least 10	
Second Report, Addendum E.	9	at least 10 but less than 100	at least 100 ...	at least 100 ...	at least 10 but less than 100
	19	at least 100 ...	at least 100 ...	at least 10 ...	at least 10
	24	at least 100 but less than 1,000	at least 100 ...	at least 100 but less than 1,000	at least 10 but less than 100
	Sept. 14	at least 1,000 ...	at least 100 but less than 1,000	at least 10 but less than 100	effluent from 6 ft. primary coke-bed now turned on to 6 ft. secondary coke-bed
	21	at least 1,000 ...	at least 100 ...	at least 100 but less than 1,000	"
	28	at least 100 but less than 1,000	at least 100 but less than 1,000	at least 100 ...	"
	Oct. 5	at least 100 but less than 1,000	at least 100 ...	at least 100 but less than 1,000	"
	12	at least 1,000 ...	at least 1,000 ...	at least 100 ...	"
	21	at least 100 but less than 1,000	at least 100 ...	at least 100 but less than 1,000	"
	26	at least 100 but less than 1,000	less than 10 ...	at least 100 ...	"
	Nov. 2	at least 10 ...	at least 10 ...	at least 10 ...	"
	9	at least 1,000 ...	at least 1,000 ...	at least 100 ...	"
	16	at least 1,000 ...	at least 100 ...	at least 100 but less than 1,000	"
	23	at least 1,000 ...	at least 100 ...	at least 100 ...	"
	30	at least 1,000 ...	at least 100 but less than 1,000	at least 100 ...	"
	Dec. 7	at least 10 but less than 100	at least 100 ...	at least 100 but less than 1,000	"
	14	at least 100 but less than 1,000	at least 10 and ? 100	at least 10 and ? 100	"
	21	at least 1,000 ...	at least 1,000 ...	? 10, less than 100	"

In summarising these results it is to be noted that—

(1) The number of spores of *B. enteritidis sporogenes* in the crude sewage and effluents varied as a rule from 10 to 1,000 per c.c. Usually there were more than 100.

(2) The bacterial treatment did not produce any significant alteration in the number of spores of this pathogenic anaërobe, and sometimes the number was greater in the effluents than in the corresponding samples of crude sewage. Possibly this may be due to the spores being stored in the coke-beds and being occasionally washed out. This supposition may also explain the observed fact that sometimes the number of spores of aerobic bacteria in the effluents was greater than in the corresponding sample of sewage. Speaking generally, and dealing only with the experiments where the samples of raw sewage and effluent corresponded, and where the absence of *B. enteritidis* was established in an amount of liquid one-tenth less than the quantity in which it was found to be present, it may be said that the number of spores of enteritidis was more often observed to be less in the effluents as compared with the corresponding sample of crude sewage than *vice versa*.

In view of these results, and remembering the virulence of this microbe and its probable relation to certain cases of acute diarrhoea in the human subject, it is remarkable that some bacteriologists still assert that the effluents from bacterial beds are free from pathogenic germs.

Another point on which some misconception is evident is the belief that because *B. enteritidis sporogenes* may be present in normal stools its presence in an effluent or in a water supply is of no moment. Passing over the fact that its numbers in normal stools are small when compared with the great numbers which are found in the excreta of patients suffering from acute diarrhoea, it is as idle to assert that because it may be present in normal stools its presence in an effluent or a water-supply is of no importance, as it would be to say that because *diplococcus pneumoniae* (one of the most pathogenic micro-organisms known) may be present in normal human saliva, its presence elsewhere in nature is not fraught with any untoward significance. Moreover, it would seem to be the case that although the spores of *B. enteritidis sporogenes* may be found in the large intestine they are usually absent from the small intestine, except in cases of acute diarrhoea, when they are present in great abundance.

In the First Report a micro-photograph* is given showing the appearances produced in sterile milk when inoculated with a minimal quantity of sewage and thereafter heated to 80 °C for ten minutes and cultivated anaërobically at blood-heat. Briefly, the casein is precipitated and torn into irregular masses by the copious development of gas, and the whey presents a nearly transparent or slightly cloudy appearance. Now, even if we forget that these characteristic changes in the milk are microbial in origin, and discard altogether the question of the pathogenicity of the micro-organisms concerned in the process, and regard the change in the medium merely as a special phenomenon to be associated with the introduction of certain substances as opposed to others, the test still remains one of extreme value. For the *particulate matter* in as much as from 100 to 500 c.c. of a pure water does not in point of fact produce these changes when added to milk, whereas the addition of as little as $\frac{1}{100}$ to $\frac{1}{1000}$ c.c. of sewage does do so. Nor do we know of any substance which is not objectionable in character or which has not been associated at some time with matter of undesirable sort which can effect a similar transformation in milk.

The only possible objection that can be urged against the test is that the fact of *B. enteritidis sporogenes* being a sporing anaërobe weakens somewhat its usefulness as an indication of recent and therefore presumably specially dangerous pollution. Of course such a contention has little or no bearing on the experiments carried out in this inquiry.

It will be noted that the spores of *B. enteritidis* often exceeded in number the total number of spores of aerobic bacteria. The reason for this probably lies in the fact of *B. enteritidis* being an anaërobe. In nature anaërobic micro-organisms are usually found to be present in the spore-form, because doubtless it is but seldom that the conditions are favourable for their anaërobic growth, and if they were not capable of forming spores under adverse circumstances they might soon lose their vitality and die. Aerobic bacteria, on the other hand, commonly find in nature the conditions favourable for their continued growth and multiplication, and so are usually met with in the vegetative form. In surface soil, however, as has been already pointed out, the ratio of spores to bacteria is very high, because the physical conditions are frequently most unfavourable to microbial life.

On comparing the figures as regards the total number of bacteria and number of spores of *B. enteritidis* no definite correspondence can be made out between the two sets of figures either in the case of the crude sewage or in the effluents. In not a few cases when the total number of bacteria was large the number of spores of *B. enteritidis* was small and *vice versa*.

It might perhaps have been anticipated that both in the case of the crude sewage and in the effluents there would be some measure of correspondence between the number of *B. coli* and the number of spores of *B. enteritidis sporogenes*. On comparing the two sets of figures it would seem that this is not the case; indeed, if there is any relation at all it is an inverse one. Thus dealing in the first place with the crude sewage only it will be noted that—

On ten different occasions the number of spores of *B. enteritidis* was very high, viz., at least 1,000 per c.c. On the corresponding dates the number of *B. coli* was five times below the average, only twice above, and on three occasions there were present the average number.

Taking next the five samples in which *B. coli* was present in great numbers, namely, 1,000,000 or more per c.c. In the corresponding samples the number of spores of *B. enteritidis* was about the average three times, less than the average once, and above the average once.

Taking next three samples in which *B. enteritidis* was present in small numbers, namely, at least 10 but less than 100 per c.c. On one of these dates *B. coli* was present in numbers exceeding one million per c.c., and in the two other samples *B. coli* was below the average.

* Fig. 14—Filtration of Sewage—First Report.

Next dealing with the ten samples in which *B. coli* was distinctly below the average, namely, those in which the number was 300,000 or less per c.c. In three of these samples the number of spores of *B. enteritidis* was over 1,000, five times the number was an average one, and in the remaining two the number was below the average.

Secondly, dealing with the effluents from the 4-foot coke-bed, a similar although perhaps less well marked want of correspondence between the number of *B. coli* and *B. enteritidis* is noticeable.

The records as regards the other coke-bed effluents are not very numerous and do not lend themselves readily to comparisons of the above sort.

In general summary of these results it may be said that—

(1) Although the total number of bacteria, the number of spores of aërobic microbes, the number of liquefying micro-organisms, the number of *B. coli*, and the number of spores of *B. enteritidis sporogenes* was, on an average, less in the effluents from the coke-beds than in the raw sewage, the reduction was not well marked, and frequently the number was actually greater in the effluents than in the corresponding samples of crude sewage.

(2) The 4-foot coke-bed yielded on the whole better results than the 6-foot primary and proved nearly as efficient as the 6-foot secondary coke-bed.

(3) There was no very definite evidence, so far as may be judged from these results, of any special selective* process being effected by the bacterial treatment of the sewage in the coke-beds, since the bacterial composition of the effluents was very much the same as that of the raw sewage.

(4) The number of microbes, both in the crude sewage and effluents, was always more than one million, but usually less than ten million per c.c.; the number of *B. coli* and spores of *B. enteritidis sporogenes* was usually more than 100,000, and at least 100, but less than 1,000, respectively, per c.c. More than one-tenth of the bacteria liquefied gelatine, and only about one in 20,000 was present in the spore form.

(5) As the bacterial composition of the effluents differed only slightly from the crude sewage, so far as this could be judged of by the records which have been enumerated, it cannot, in the absence of direct proof to the contrary, be safely considered that the effluents from the coke-beds are less dangerous than the raw sewage in their possible relation to disease.

It must, however, be remembered that in the present case there are practical points which first of all demand consideration. In this connexion it will not be out of place to quote from page 21 of the Second Report.

Thus in dealing with the general results obtained at Crossness it was said—"It must be admitted that the above results are not satisfactory from the bacteriological point of view, particularly when it is remembered that an effluent ought to be judged, not only by the percentage amount of purification effected, but also by the *actual state* it is in. Yet it is to be considered that these results assume a different complexion when viewed side by side with the chemical data.

"It has been shown in Division I. of this Report that the percentage purification, as judged from the dissolved oxidisable matter removed by the treatment, was on an average 50 per cent., and that the suspended matter was entirely removed. It has been stated that the results thus obtained surpass considerably those yielded by chemical treatment and appear to justify the claims put forward by the supporters of the biological treatment of sewage, especially since, so far as can be seen, no nuisance or danger arises as a result of the treatment.

"In the body of the Report a number of reasons are given, showing that it is unwise in the present state of our knowledge to recklessly condemn an effluent on bacteriological ground alone, without full knowledge of all the requirements of the case. In the attempt to treat sewage on biological lines it is to be noted that the solution of the suspended matter and even the considerable destruction of putrescible matters by microbial agencies afford sufficient ground for justifying the process, at all events as a preliminary measure. Whether this preliminary treatment is to be supplemented by further treatment, either by passage through other coke-beds, or by land irrigation or by any other method, is a matter largely dependent on circumstances.

"In the present case there are practical points which first of all demand consideration, and although it may be most desirable to obtain an effluent chemically pure and bacteriologically above suspicion of danger it is to be thought of that an effluent not altogether satisfactory in one or other, or even in both, of these respects may yet fulfil all necessary requirements without passing out of the range of practicability. In certain cases it may be imperative to obtain an effluent bacteriologically sound, but it does not follow that a similar result is urgently called for in other cases, as, for example, where an effluent is turned into a watercourse which is not used for drinking purposes, and which already may contain practically all the bacteria that are found in sewage.

"It might reasonably be argued that where an effluent is turned into a river already grossly polluted and below the lowest level of "intake" for waterworks purposes, the chemical state of such effluent was (from the practical point of view, at all events) of possibly even greater importance than the bacteriological. Some such state of things pertains in the case of London sewage and the river Thames. Here the initial consideration is to avoid fouling the river with

* That, however, some selective process is at work in the coke-beds need hardly be doubted. For example, raw sewage contains little or no oxidised nitrogen, whereas the effluents from bacterial beds contain nitrites, and nitrates often in considerable amount. This alteration in the chemical state of the liquid is brought about by nitrifying bacteria, and it is highly probable that these particular microbes multiply and accumulate in the coke-beds, and that the effluents from *mature* coke-beds contain more nitrifying organisms than the crude sewage. Some experiments of a tentative character which I have carried out seem to support this hypothesis.

putrescible matters to such an extent as to constitute a grave public nuisance. From this point of view it is evident that an effluent rich in putrescible matter is not permissible, but it is not as certain that an effluent rich in bacteria is equally to be condemned on practical grounds."

Methods.—For a description of the various methods employed the Report itself must be consulted (pages 22, 23, 24, 25, 27). Here it is permissible only to give the amounts of crude sewage or effluents to be added to the nutrient media in order to obtain the best results with the different processes.

Total number of bacteria—From $\frac{1}{100,000}$ to $\frac{1}{10,000}$ c.c. ...	...	Gelatine plate cultures, incubated at 20° C.*
Spores of aerobic bacteria—From $\frac{1}{10}$ to 1 c.c. ...	...	Gelatine plate cultures. Cultures previously heated to 80° C. for 10 minutes. (Incubated at 20° C.)
Liquefying bacteria—From $\frac{1}{100,000}$ to $\frac{1}{10,000}$ c.c.	...	Surface gelatine plate cultures. (Incubated at 20° C.)
B. coli—From $\frac{1}{100,000}$ to $\frac{1}{10,000}$ c.c. ...	...	Surface phenol (0.05 per cent.) gelatine plate cultures. (Incubated at 20° C.)†
Spores of B. enteritidis sporogenes— $\frac{1}{10,000}$; $\frac{1}{1,000}$; $\frac{1}{100}$; $\frac{1}{10}$ c.c.		Milk cultures, heated to 80° C. for 10 minutes, and cultivated anaerobically. (Incubated 37° C.)‡

The Biological Treatment of Sewage (Section I., pages 18-20, Second Report).

In speaking of the discoveries which have paved the way towards a scientific knowledge of the true nature of putrefactive processes, it was said that—

"One of the most important discoveries of recent times was that made by Schloësing and Muntz in 1877. They proved that nitrification, or the oxidation of ammonia to nitric acid, is due to the vital activity of bacteria, and thus carried a stage further the important discovery by Schwann and Schultze (1839) that micro-organisms are the true agents of decomposition. Later, Winogradsky and others described and isolated, in pure culture, nitrifying organisms."

"Pasteur, following up the researches of Cagniard and Schwann, demonstrated, in 1857, the relation between lactic, acetic, and butyric fermentations and special organisms."

In discussing the aim and object of the biological treatment of sewage it was pointed out that—

"In nature the following cycle of transformation takes place. Dead organic matter decays as the result of the vital activity of bacteria, and ammonia is liberated. The nitrifying organisms bring about the oxidation of the ammonia, first to nitrous and then to nitric acid. These acids by reaction upon the bases, always present, form nitrites and nitrates, and these nourish the living plant. While the nitrogen is undergoing these changes, the carbon of the organic matter is converted into carbonic acid, and the hydrogen mainly into water. To some extent also the nitrogen and hydrogen are liberated in the free gaseous state."

Further, that—

"The organic matters found in sewage are partly in suspension and partly in solution, and sewage contains in itself the necessary living germs for the destruction of both these forms of organic matter. The aim and object of the biological treatment of sewage is to render soluble by microbial agencies the solid matters; and to split up by the action of living bacteria both the matter thus dissolved and organic compounds which were originally in solution into their simpler elements. In the final process of purification, these substances should undergo oxidation induced by the life processes of nitrifying organisms, and an effluent should be produced which is free from putrescible matter and contains only inorganic or mineral substances."

Two of the most remarkable phenomena to be observed in the study of biological coke-beds are (1) the almost complete removal of the suspended matters, and (2) the production of effluents which, although they usually still contain a quite appreciable amount of oxidisable organic matter, are, as a rule, *non-putrescible* so far. Indeed, as this may be judged of by storing them in (a) completely filled and stoppered bottles and (b) partially filled and stoppered bottles.

It appears quite certain that the non-putrescible character of many effluents from bacterial coke-beds is not due to the absence of putrefactive bacteria. This is, of course, very evident from the numerous records which have been given of the bacterial composition of the Crossness effluents. In particular, the following paragraph (page 27, Second Report) is worth quoting—

"In experiments 9 and 10 (col. 5, Table I.) it was sought to discover the smallest amount of crude sewage and of effluent which in broth cultures at 20° C. would produce growth, indol reaction and offensive smell. No growth occurred in either case, when as little as 0.0000001 c.c. was inoculated into the broth; but when 0.000001 c.c. was used, growth occurred both in the case of the crude sewage and of the effluent, and the cultures had an offensive smell and gave indol reaction."

Probably the explanation lies, in part at all events, in a change in the *character* of the organic matter still remaining in the effluents. Possibly also the liquid acquires some quality inhibiting the putrefactive bacteria from exerting their putrescent effect.

Some stress was laid upon the fact that in certain cases "it may not be necessary to attempt the complete purification of the sewage, the solution of the suspended matters and partial destruction of the putrescible matters being all that is urgently called for, as, for example, where the

* In illustration of such cultures see Plate 1. fig. No. 2, First Report.

† " " " Plate 1, fig. No. 1, First Report.

‡ " " " Plate 1, fig. No. 14, First Report.

effluent is of relatively small bulk and is turned into a stream which is not used for domestic purposes (as is the case in the lower Thames) or else when the effluent is to be subsequently treated by land irrigation." And it was asserted that "the mere solution of the great mass of the suspended matters by bacterial agencies, which is, perhaps, common to all the different processes at present under trial, is a sufficient vindication of the enormous advantage to be gained by the biological treatment of sewage."

In conclusion reference was made to the systems of sewage disposal advocated by Messrs. Scott-Moncrieff, Cameron, Ducat, Dibdin and Thudichum, etc.

In Table I. (pages 28 to 31) the results were given of the bacteriological examination of Crossness crude sewage, the effluent from the 4-foot coke-bed, the effluent from the 6-foot coke-bed, and the effluent from the laboratory vessel (effluent from 6-foot coke-bed again treated in the laboratory at Crossness).

Most of the results recorded in this table have already been summarised, but it is worthy of note that besides searching for *B. enteritidis* and *B. coli* the attempt was also made to estimate the number as well as the character of other microbes present in the crude sewage and effluents, and that notes under this heading are recorded in the table.

Thus, the micro-organism called "*sewage proteus*"* was found to be present in great numbers (usually more than 100,000 in 1 c.c.) both in the crude sewage and effluents.

In Table 2 (pages 32-33) the results were shown of the bacteriological examination of the effluents from the Crossness and Barking Outfall Works and of the water of the River Thames. As regards the effluents from the Barking and Crossness precipitation tanks it may be said that they were no better, if, indeed, they were not worse than average samples of crude sewage. As regards Thames water, samples were taken at Greenhithe and Barking in such a way as to avoid, as far as this was possible, the influence of sewage discharge. These samples in their bacterial composition resembled dilute crude sewage. Samples were also collected high up the river, namely (1) between Sunbury and Hampton, just above the intake of the Southwark and Vauxhall Water Company (dry weather) and (2) at Twickenham (very wet weather). The former contained 40 gas-forming *B. coli* in 1 c.c. *B. enteritidis sporogenes* was present in 300 c.c. (1 c.c. of the culture killed a guinea-pig in less than 24 hours), but not in 100 c.c. The latter contained 100 gas-forming *B. coli*, and at least 10, but less than 100 spores of *B. enteritidis* per. c.c.

Thus it will be seen that Thames water at Barking and Greenhithe was no better than dilute crude sewage, and even as high up as near Hampton and Twickenham showed distinct evidence of pollution of the most objectionable kind.

These experiments were undertaken with a two-fold object.

In the first place to show that the effluents from the chemical precipitation tanks were no better, if, indeed, they were not worse than the effluents from the bacterial coke-beds, and secondly to demonstrate the fact that Thames water is already grossly polluted, and contains practically all the bacteria to be found in the effluents.

In section V. (pages 33-40) a description was given of some of the bacteria found in the crude sewage and in the effluents from the coke-beds.

In illustration of the Report there were 14 diagrams, 24 micro-photographs, and 4 diagrammatic drawings.

3.—SUMMARY OF THE CONTENTS OF THE SUPPLEMENT TO THE SECOND REPORT.†

In this Report a description was given of the results of the bacteriological examination of the deposit which accumulates on the coke of the coke-beds. The Report covered work carried out during May, June, and July, 1899.

A sample of the deposit from the coke-bed at Barking contained 1,800,000 microbes; and at least 10,000 but less than 100,000 spores of *B. enteritidis sporogenes* per gramme. Further, two mice inoculated with small portions of the deposit died of tetanus.

Stained, as for tubercle, a large number of "acid-fast" bacteria were found in the deposit. Other samples of deposit from the same and from other coke-beds were also found to contain these bacteria; and when crude sewage and effluents from coke-beds were centrifugalised and the deposit stained a similar result was obtained. Experiments on animals were negative with one exception; in this case the animal died of true tuberculosis.

In concluding the report it was said that—

I. In crude sewage, in bacterial coke-beds, and in the effluents from bacterial beds there are certain bacteria which, after being stained with hot carbol fuchsin, resist decolorisation with 33 per cent. nitric acid.

II. Some of these "acid-fast" bacteria cannot, with certainty, be morphologically distinguished from the *tubercle bacillus*.

III. In one instance a guinea-pig inoculated with the deposit accumulating on the coke of a bacterial bed died, and presented on examination the appearance of death from tubercle infection, and sections of its organs, when appropriately stained, showed the presence of numerous *tubercle bacilli*.

In illustration of the Report there were 10 micro-photographs and 1 coloured drawing.

* A full description of the morphological and biological characters of this bacillus is given on pages 36 and 37 of the Second Report.

† Supplement to the Second Report. Notes on the deposit which accumulates on the coke fragments of the coke-beds at Crossness.

II.—THE EXPERIMENTS ON BACTERIAL TREATMENT AT BARKING.

It will be remembered that in the First Report the results were given of the examination of nine samples of Barking crude sewage. In the Second Report the results of the bacterial treatment of the sewage in coke-beds at Crossness were given. Here it is proposed to deal with somewhat similar experiments carried out at Barking.

I.—THE COKE AND RAGSTONE BEDS.*

The beds were four in number, namely, two of coke (coarse and fine), and two of ragstone (coarse and fine).

Some of the experiments with the effluents as regards their effect on animals are recorded elsewhere (experiments on animals, p. 68), and it will be remembered that the Supplement to the Second Report dealt chiefly with the deposit accumulating upon the coke in the coke-beds at Barking.

The effluents were chiefly examined for the presence of *B. enteritidis sporogenes*, and the results obtained in this direction are given in the form of a Table. But on March 16, 1899, a sample of Barking crude sewage, and the effluents from the fine ragstone-bed and the fine coke-bed were further examined for the total number of bacteria and number of *B. coli*. The results were as follows:—

Barking crude sewage	...	10,000,000 bacteria in 1 c.c.	...	600,000 <i>B. coli</i> in 1 c.c.
Effluent from fine ragstone-bed		4,000,000 bacteria in 1 c.c.	...	500,000 <i>B. coli</i> in 1 c.c.
		(60 per cent. reduction.)		(16 per cent. reduction.)
Effluent from fine coke-bed	...	1,800,000 bacteria in 1 c.c.	...	300,000 <i>B. coli</i> in 1 c.c.
		(82 per cent. reduction.)		(50 per cent. reduction.)

The following is a Table of the results as regards *B. enteritidis sporogenes* (Klein)—

TABLE 1.—NUMBER OF SPORES OF *B. ENTERITIDIS SPOROGENES* (KLEIN).

Date.	Barking crude sewage.	Effluents from the coke and ragstone beds at Barking.			
		Coke.		Ragstone.	
		Coarse.	Fine.	Coarse.	Fine.
1899					
Jan. 26	+ '01 and '001 c.c.	...	+ '01 and '001 c.c.	...	+ '01; — '001 c.c.
Feb. 2	+ '01 and '001 c.c.	+ '01; — '001 c.c.	+ '01; — '001 c.c.	+ '01 and '001 c.c.	+ '01 and '001 c.c.
9	+ '01 and '001 c.c.	+ '01; — '001 c.c.	+ '01; — '001 c.c.	+ '01 and '001 c.c.	+ '01; — '001 c.c.
15	+ '01 and '001 c.c.	+ '01 and '001 c.c.	+ '01 and '001 c.c.	+ '01 and '001 c.c.	+ '01 and '001 c.c.
Mar. 8	+ '01 c.c....	+ '01 c.c....	+ '01 c.c....	+ '01 c.c....	+ '01 c.c.
16	+ '01 c.c....	...	— '01 c.c....	...	+ '01 c.c.
Apr. 13	+ '01 c.c....	— '01 c.c....	— '01 c.c....	+ '01 c.c....	— '01 c.c.

The sign + signifies the presence and the sign — the absence of the spores of *B. enteritidis sporogenes*.

These results are shown in graphic form in Diagram 1.

It might have been anticipated that the fine beds would have produced a significant alteration in the number of spores of this pathogenic anaërobe. Such, however, was not the case, and although the number in the effluents was usually less than in the corresponding samples of crude sewage, the reduction was not very well marked, and was not, moreover, a constant feature. There did not seem to be any striking difference between the coarse and fine beds, or between the two kinds of material (coke and ragstone) as regards the number of spores of *B. enteritidis*.

2.—THE DOUBLE COKE-BEDS.

These coke-beds are known as—

The primary coarse coke-bed, series A	} A description of these beds will be found in the Chemical Division of the Report.
The secondary „ „ „ „	
The primary „ „ „ „ B	
The secondary fine „ „ „ „	

From October 16, 1899, to January 17, 1900, the new beds at Barking were under bacteriological observation.

The results obtained will be dealt with briefly as follows—

(a) TOTAL NUMBER OF BACTERIA (GELATINE AT 20° C.).

The number of micro-organisms in the crude sewage and effluents is given in the following Table—

* A description of these beds will be found in the Chemical Division of the Report.

Table 2.—Total number of bacteria in 1 c.c.

Date.	Barking crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B
1899.					
October 16 ...	7,200,000	1,700,000	800,000	...	...
23 ...	5,440,000	1,500,000	...	...	900,000
November 1 ...	8,800,000	2,640,000	2,000,000	...	...
7 ...	7,060,000	...	...	1,070,000	400,000
13 ...	3,680,000	...	1,180,000	910,000	...
28 ...	10,400,000	...	...	4,800,000	2,640,000
December 5 ...	...	...	1,480,000	4,520,000	1,000,000
12 ...	...	...	2,240,000	2,900,000	1,420,000
1900.					
January 3 ...	...	2,880,000	3,970,000	...	2,530,000
17 ...	...	...	1,760,000	2,000,000	1,220,000

These results are shown in graphic form in Diagram 2.

It is to be noted that on four occasions one or other of the effluents contained less than one million microbes per c.c., and on fifteen occasions not more than two millions. On November 7th the effluent from the secondary fine bed (series B.) contained only 400,000 microbes per c.c., as compared with 7,060,000 in the crude sewage, a reduction of over 94 per cent.

(b) NUMBER OF *B. COLI* OR CLOSELY ALLIED FORMS.

The number of *B. coli* in the crude sewage and effluents is shown in the following Table—

Table 3.—Number of *B. coli*, or closely allied forms, in 1 c.c.

Date.	Barking crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B.
1899.					
October 16 ...	800,000	None in '00001 c.c.	100,000	...	...
23 ...	200,000	800,000	...	...	None in '00001 c.c.
November 1 ...	1,600,000	500,000	500,000	...	...
7 ...	1,200,000	...	...	200,000	None in '00001 c.c.
13 ...	600,000	...	300,000	None in '00001 c.c.	...
28 ...	200,000	...	...	200,000	100,000
December 5 ...	...	...	100,000	100,000	None in '00001 c.c.
12 ...	...	...	100,000	400,000	400,500
1900.					
January 3 ...	...	200,000	100,000	...	200,000
17 ...	...	...	None in '00001 c.c.	100,000	None in '00001 c.c.

These results are shown in graphic form in Diagram 3.

It will be noted that on seven occasions one or other of the effluents contained no *B. coli* in '00001 c.c. Usually, however, the effluents contained at least 100,000 *B. coli* per c.c.

Although there was evidence of a reduction in the number of *B. coli* in the effluents as compared with the crude sewage, the large number still remaining in the effluents must be regarded as very unsatisfactory from the epidemiological point of view.

(c) NUMBER OF SPORES OF *B. ENTERITIDIS SPOROGENES*.

The number of spores of *B. enteritidis sporogenes* is shown in the following Table—

Table 4.—Number of spores of *B. enteritidis sporogenes* (Klein).

Date.	Barking crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B.
1899	c.c.	c.c.	c.c.	c.c.	c.c.
Oct. 16	+ '1, '01 and '001	+ '1 and '01; — '001	+ '1, '01 and '001	...	+ '1 and '01; — '001
23	+ '1, '01 and '001	+ '1, '01 and '001	...	...	+ '1 and '01; — '001
Nov. 1	+ '1, '01 and '001	+ '1, '01 and '001	+ '1, '01; — '001	...	...
7	+ '1, '01 and '001	...	...	+ '1 and '01; — '001	+ '1 and '01; — '001
13	+ '01; — '001	...	+ '01; — '001	+ '01; — '001	...
28	+ '1 and '01	...	...	+ '1 and '01	+ '1 and '01
Dec. 5	...	...	+ '01; — '001	+ '01 and '001	+ '01; — '001
12	...	...	+ '01 and '001	+ '01 and '001	+ '01; — '001
1900					
Jan. 3	...	+ '01; — '001	+ '01 and '001	...	+ '01; — '001
17	...	...	+ '01	+ '01	— '01

The sign + signifies the presence and the sign — the absence of spores of *B. enteritidis sporogenes*.

These results are shown in graphic form in Diagram 4.

Although as a rule the effluents contained fewer spores of *B. enteritidis sporogenes* than the crude sewage, the reduction was not very well marked, and, moreover, was not a constant factor.

It cannot therefore be said that the biological processes at work in the coke-beds effected any significant alteration in the number of spores of this pathogenic anaërobe.

(d) CONCLUDING REMARKS.

On November 1st, 1899, *B. pyocyaneus** was isolated from $\frac{1}{1000}$ c.c. of the effluent from the second coarse bed (series A). It was very virulent, 1 c.c. of a 24 hours broth culture killing a guinea-pig in less than 24 hours. The same micro-organism was isolated in pure culture from the heart's blood, etc., of the animal. (See fig. 5, Plate II.)

On December 6th, 1899, three strains of "*sewage proteus*" were isolated from $\frac{1}{10000}$ c.c. of the effluent from the primary coarse bed (series B). They all liquefied gelatine very rapidly, they were actively motile, and produced "gas" in 24 hours in gelatine "shake" cultures. One of the strains killed a guinea-pig in 24 hours (1 c.c. of broth culture); another was not so virulent, ulceration occurred at the site of the inoculation, and the animal recovered; the third produced only a slight local reaction. This latter non-virulent strain of "*sewage proteus*" was used to inoculate the 13-feet coke-bed at Crossness (see page 75).

On November 1st, 1899, streptococci xix., xx., and xxi., were isolated from $\frac{1}{1000}$ c.c. respectively of the effluent from the primary coarse bed (series A), the effluent from the secondary coarse bed (series A), and the crude sewage. (See pages 66 and 67.)

During a considerable period of the enquiry, attention was directed to the study of the *thermophilic* bacteria. It was suggested to me, by Dr. Gordon, that a comparison of their numbers in the crude sewage and effluents might be of value.

These micro-organisms (*B. thermophilus* and its allies) have been shown to be present in the alimentary canal of human beings and mammals, in sewage, in sewage-contaminated waters, and in soil, but not in pure waters.

It was found that *thermophilic* bacteria§ (capable of growing luxuriantly in broth culture at a temperature of 60-70° c.) were present in London crude sewage in abundance. They were also present, although usually in smaller proportion, in the effluents from the coke-beds.

It has been suggested that the presence or absence of these bacteria in a water supply might be employed as a test of potability. But, in my experience, *thermophilic* bacteria are present in numbers in soils *not recently* polluted and are often absent from waters known to be *freshly* contaminated with objectionable matters, waters, moreover, which, by more reliable and delicate bacteriological tests, can readily be shown to be dangerously polluted.

Certainly the presence of *thermophilic* bacteria in a water would lead one to suspect *gross* contamination, but their absence could hardly be regarded as testifying to purity or "safety."

Nevertheless, the test, as a rough indication of the probable biological quality of a liquid and as a means of comparing different liquids, e.g., crude sewage and bacterial effluents, is one not devoid of value.

III.—THE EXPERIMENTS ON BACTERIAL TREATMENT AT CROSSNESS.

1.—FURTHER EXPERIMENTS WITH THE EFFLUENTS FROM THE 4-FOOT, 6-FOOT (PRIMARY), AND 6-FOOT (SECONDARY) COKE-BEDS AT CROSSNESS.

In the Second Report the bacteriological results were brought up to the end of December, 1898. In the early part of the year 1899 some further experiments were carried out with the effluents from the 4-foot, 6-foot (primary), and 6-foot (secondary) coke-beds. These took the form of comparative determinations of the number of spores of anaërobic bacteria in the raw sewage and in the effluents from the coke-beds.

NUMBER OF SPORES OF ANAËROBIC BACTERIA IN CROSSNESS CRUDE SEWAGE AND IN THE EFFLUENTS FROM THE COKE-BEDS.

The effect of the bacterial treatment of the raw sewage in coke-beds as regards the number of spores of *anaërobic* bacteria was to a considerable extent covered by the comparative determinations of the number of spores of *B. enteritidis sporogenes* in the raw sewage and in the effluents, carried out since February, 1898. Nevertheless, it was considered advisable to supplement those records with a series of experiments dealing with the number of spores of anaërobic bacteria of all kinds in the raw sewage and in the effluents capable of growing at 37° C. in agar under anaërobic conditions.

Table 5.—Number of spores of anaërobic bacteria in 1 c.c. [Agar at 37° C.]

Date.	Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke-bed.
1899.				
January 11 ...	1,988	720	920	No record
18 ...	304	380	424	224
25 ...	424	516	232	336
February 1 ...	201	100	191	197
8 ...	The growths spread over the surface of the medium, preventing accurate counting.			
15 ...	148	212	160	124
22 ...	262	128	196	156

The agar tubes were boiled for half-an-hour, rapidly cooled to 80° C., inoculated with the sewage or effluent, and heated to 80° C. for 10 minutes. The contents were next poured into plates, and these were immediately placed in an air-tight chamber containing a freshly-prepared mixture of pyrogallic acid and potassium hydrate solution. These results are shown in graphic form in Diagram 5.

* See fig. 5. This micro-organism (*B. Pyocyaneus*) must not be confused with the ordinary liquefying fluorescent bacillus (*B. fluorescens liquefaciens*) of sewage, soil and water. *B. fluorescens liquefaciens* does not grow, or only imperfectly, at blood-heat, and is not virulent; and differs in a number of other important respects from *B. Pyocyaneus*.

§ Figs. 9 and 10 show the morphological appearance of *B. Thermophilus* or an allied form. The micro-organism represented in the micro-photographs was isolated from London crude sewage: it grew luxuriantly at a temperature of 60-70° C.

Excluding the results obtained on January 11th, as the figures are abnormally high, and there is no record on that date for the 6-foot secondary coke-bed, the averages are as follows—

Average number of spores of anaërobic bacteria in five samples of Crossness crude sewage, and in five comparative effluents from the 4-foot, 6-foot (primary), and 6-foot (secondary) coke-beds, 268; 267; 240; and 207 per c.c. respectively.

It will be seen from these results that the bacterial treatment of the crude sewage in the coke-beds did not effect any marked alteration in the number of spores of anaërobic bacteria. Indeed the number in the effluent from the 4-foot coke-bed was practically the same as in the raw sewage, and in the case of the effluents from the 6-foot (primary) and 6-foot (secondary) coke-beds the reduction was only 10 and 22 per cent. respectively.

Pressure of other work for the Council made it impossible to study fully the morphological and biological characters of the different kinds of anaërobic bacteria isolated in pure culture from the anaërobic agar plates; and the notes under this heading are of too fragmentary a character to make it advisable to place them on record. So far as could be made out there was no difference as regards species of microbes between the anaërobic cultures made from the crude sewage and those made from the effluents from the coke-beds.

The appearance presented by the colonies (superficial and deep) under a low power of the microscope is shown diagrammatically in Plate V., fig. C. So far as could be judged by observation under a low power of the microscope and by making sub-cultures the number of spore-forming anaërobes of different species was not great. As regards growth in anaërobic milk culture some of the microbes isolated from the agar plate cultures produced precipitation of the casein, with abundant development of gas, the whey remaining nearly transparent, or presenting only a slightly cloudy appearance; others produced no visible change even after several days incubation at 37° C.; others again gave rise to an appearance resembling slow peptonization, beginning just below the surface, and gradually extending downwards in cylindrical fashion.

A rise or fall above or below the mean in the number of the spores of anaërobic bacteria in the crude sewage was usually associated with a similar increase or decrease in the number of spores of anaërobes in the effluents from the 4-foot, 6-foot (primary), and 6-foot (secondary) coke-beds.

In conclusion, and as an addition to the records of the bacterial composition of Crossness crude sewage, it may be worthy of note that the number of spores of anaërobic bacteria (agar at 37° C.) in Crossness crude sewage is usually between 200 and 300 per c.c.

2.—EXPERIMENTS WITH THE EFFLUENTS FROM THE 13-FOOT COKE-BED AT CROSSNESS.*

The chief results obtained will be given under the following headings—

- (a) Total number of bacteria (gelatine at 20° C.).
- (b) Number of *B. coli* or closely allied forms.
- (c) Number of spores of *B. enteritidis sporogenes* (Klein).
- (d) Number of bacteria capable of growing in agar at 37° C.

(a) TOTAL NUMBER OF BACTERIA (GELATINE AT 20° C.).

The results as regards the total number of bacteria are given in the following table—

Table 6.—Showing the total number of bacteria in 1 c.c.

Date.		Crossness crude sewage.	Effluent from the 13 ft. coke-bed at Crossness.
1899.			
March	22	5,000,000	2,000,000
May	11	4,600,000	3,000,000
July	5	7,200,000	16,000,000
August	2	4,110,000	8,000,000
September	1	2,240,000	1,940,000
	7	3,910,000	1,490,000
	13	11,170,000	5,040,000
	19	9,580,000	6,750,000
	27	5,000,000	4,100,000
October	4	4,300,000	5,320,000

These results are shown in graphic form in Diagram 6.

It is to be noted that the average numbers of microbes in the crude sewage and in the effluent from the 13-foot coke-bed were 5,711,000 and 5,364,000 per c.c. respectively. This means a reduction of only 6 per cent., the reason being that on July 5th and August 2nd the effluent contained a much larger number of micro-organisms than the raw sewage. On all other occasions, with one exception (October 4th), the effluent contained fewer bacteria than the corresponding samples of crude sewage. A rise or fall above or below the mean in the total number of microbes in the raw sewage was coincident with a similar increase or decrease in the number of germs in the corresponding samples of effluent on eight occasions. In the remaining three cases this relationship was not observed.

* A description of this bed will be found in the Chemical Division of the Report.

(b) NUMBER OF *B. COLI* OR CLOSELY ALLIED FORMS.

The results, as regards *B. coli*, are given in the following table—

Table 7.—Number of *B. coli* or closely allied forms per c.c.

Date.		Crossness crude sewage.	Effluent from the 13 ft. coke-bed at Crossness.
1899.			
March	22	100,000	100,000
May	11	700,000	200,000
July	5	None in 0·00001 c.c.	None in 0·00001 c.c.
August	2	900,000	400,000
September	1	400,000	200,000
	7	300,000	100,000
	13	500,000	900,000
	19	1,900,000	900,000
	27	500,000	300,000
October	4	600,000	600,000

These results are shown in graphic form in Diagram 7.

The Table shows that on one occasion the number of *B. coli* was greater in the effluent from the 13-foot coke-bed than in the corresponding sample of raw sewage. In nearly all the other cases the crude sewage contained the larger number. Nevertheless, although on an average the bacterial treatment of the crude sewage effected a reduction in the number of *B. coli*, the number actually remaining in the effluents was very large—usually more than 100,000 per c.c.

(c) NUMBER OF SPORES OF *B. ENTERITIDIS SPOROGENES* (KLEIN).

The results, as regards *B. enteritidis sporogenes*, are given in the following table—

Table 8.—Showing the number of spores of *B. enteritidis sporogenes* (Klein).

Date.		Crossness crude sewage.	Effluent from the 13 ft. coke-bed at Crossness.
1899.			
March	22	+ '01 c.c.	+ '01 c.c.
April	12	+ '01 and '001; — '0001 c.c. ...	+ '01; — '001 c.c.
	19	+ '01; — '001 c.c.	+ '01; — '001 c.c.
	27	+ '001; — '0001 c.c.	+ '01; — '001 c.c.
May	4	+ '01 and '001; — '0001 c.c. ...	+ '01; — '001 c.c.
	11	+ '01; — '001 c.c.	— '01 c.c.
	18	+ '01; — '001 c.c.	— '01 c.c.
July	5	+ '01; — '001 c.c.	+ '1; — '01 c.c.
August	2	+ '1 and '01; — '001 c.c.	+ '1 and '01; — '001 c.c.
September	1	+ '1, '01 and '001 c.c.	+ '1 and '01; — '001 c.c.
	7	+ '1 and '01; — '001 c.c.	+ '1, '01 and '001 c.c.
	13	+ '1, '01 and '001 c.c.	+ '1, '01 and '001 c.c.
	19	+ '1, '01 and '001 c.c.	+ '1 and '01; — '001 c.c.
	27	+ '1 and '01; — '001 c.c.	+ '1 and '01; — '001 c.c.
October	4	+ '1 and '01; — '001 c.c.	+ '1 and '01; — '001 c.c.

The sign + signifies the presence and the sign — the absence of the spores of *B. enteritidis sporogenes*.

These results are shown in graphic form in Diagram 8.

It is to be noted that although the number of spores of *B. enteritidis sporogenes* was frequently less in the effluents from the 13-foot coke-bed than in the corresponding samples of crude sewage, the *actual* number of spores remaining in the effluent after the bacterial treatment of the sewage was very large—usually at least 100, but less than 1,000 in 1 c.c.

(d) NUMBER OF BACTERIA CAPABLE OF GROWING IN AGAR AT 37° C.

In the Second Report (page 27) it was pointed out that—"In experiments 3 and 5 (col. 5, Table I.) the number of bacteria in the crude sewage capable of growing at 37° C. in agar was estimated. The numbers were 1,260,000 and 1,171,000 per c.c., as compared with 3,670,000 and 6,400,000 obtained by gelatine plate cultivation at 20° C. A similar experiment (experiment 4) with the effluent from the 4-foot coke-bed gave 1,630,000 (agar at 37° C.) as compared with 4,100,000 (gelatine at 20° C.) bacteria per c.c."

At the period (May, 1898) when these experiments were carried out the pressure of other important work prevented a series of experiments being carried out on the above lines. It, however, was considered important to extend these observations at as early a date as possible.

The following Table gives the number of bacteria (agar at 37° C.) in Crossness crude sewage and in the effluent from the 13-foot coke-bed. It also gives, for comparative purposes, the number of bacteria (gelatine at 20° C.) in the corresponding samples.

Table 9.—Showing the number of bacteria (agar at 37° C. and gelatine at 20° C.) in seven samples of Crossness crude sewage, and seven samples of the effluent from the 13 ft. coke-bed.

Date.	Number of bacteria in 1 c.c.			
	Crossness crude sewage.		Effluent from the 13 ft. coke-bed.	
	Agar at 37° C.	Gelatine at 20° C.	Agar at 37° C.	Gelatine at 20° C.
1899.				
August 2 ...	2,660,000	4,110,000	2,540,000	8,000,000
September 1 ...	1,660,000	2,240,000	670,000	1,940,000
7 ...	1,530,000	3,910,000	930,000	1,490,000
13 ...	6,830,000	11,170,000	5,210,000	5,040,000
19 ...	5,270,000	9,580,000	4,020,000	6,750,000
27 ...	2,600,000	5,000,000	2,400,000	4,100,000
October 4 ...	2,510,000	4,300,000	3,850,000	5,320,000

These results are shown in graphic form in Diagram 9.

The Table shows that the average number of bacteria (agar at 37° C.) in the crude sewage and in the effluent was 3,294,444 and 2,802,857 respectively per c.c., showing a reduction of about 14 per cent. Further, that the average number of bacteria (gelatine at 20° C.) in the crude sewage and in the effluents was 5,758,571 and 4,662,857 respectively per c.c., i.e., a reduction of about 19 per cent.

Comparing the figures 3,294,444 (agar at 37° C.) and 5,758,571 (gelatine at 20° C.) it is to be noted that the difference is 42 per cent., hence more than one-half of the number of bacteria capable of growing in gelatine at 20° C. can likewise grow in agar at 37° C. When a similar comparison is made as regards the effluents from the 13-foot coke-bed the difference is 39 per cent.

It is evident from these results that the bacterial treatment of the sewage in the coke-beds did not effect any marked reduction in the number of *blood-heat* organisms; indeed, the reduction was less as regards these germs than as regards the bacteria growing in gelatine at 20° C.

Although gelatine is doubtless a more favourable medium than agar for the growth of bacteria of all sorts, it is not the difference of nutrient medium, but of temperature which chiefly accounts for the difference in the numbers under the two sets of conditions. As a matter of fact the number of bacteria in sewage capable of growing at 37° C. is both actually very great and is very great also in relation to the total number of microbes growing at the ordinary temperature, the reason apparently being that so many of the micro-organisms found in sewage are derived from the intestinal discharges of animals, e.g., *B. coli*, which has been shown to be present in numbers usually exceeding 100,000 per c.c.

In pure waters the number of "*blood-heat*" bacteria is usually small, and their ratio to the number of germs growing at the ordinary temperature is likewise small.

Although a large number of "*blood-heat*" bacteria is considered a bad sign, it must not be supposed that all the different species of microbes capable of growing at 37° C. are harmful. Many found in sewage and elsewhere in nature are, so far as we know, quite unobjectionable, e.g., *B. subtilis*, *B. mesentericus*, *B. mycoides*, etc. On the other hand others are decidedly objectionable and may be pathogenic, e.g. *B. coli* and *B. proteus* (certain forms), and some are definitely pathogenic, e.g., *B. pyocyaneus*. In the Second Report (page 27) it was stated—"A cultivation of *B. pyocyaneus* isolated from a sample of Crossness crude sewage proved to be extremely virulent. Thus 1 c.c. of a twenty-four hours' broth culture (at 37° C.) injected subcutaneously into a guinea-pig killed the animal in less than twenty-four hours, and the organism was recovered in pure culture from the heart's blood, spleen, etc."

On November 1, 1899, *B. pyocyaneus** was isolated from $\frac{1}{1000}$ c.c. of the effluent from the secondary coarse bed (series A) at Barking. A guinea-pig injected subcutaneously with 1 c.c. of a twenty-four hours' broth culture (at 37° C.) died in less than twenty-four hours, and the same micro-organism was isolated in pure culture from its heart's blood.

In the light of this result (apart from the numerous records contained in this and previous Reports of equal or greater significance) it is strange that many still consider the effluents from coke-beds and in general from bacterial processes, non-pathogenic.

So far as may be judged by a rise or fall above or below the mean, the figures show that both as regards the crude sewage and the effluents there was a decided parallelism between the number of bacteria growing in agar at 37° C. and the number growing in gelatine at 20° C. Similarly, a rise or fall above or below the mean in the number of bacteria capable of growing in agar at 37° C. in the crude sewage was nearly always coincident with a rise or fall in the number of microbes in the corresponding effluents from the 13-foot coke bed.

In conclusion, and by way of addition to the chief results which have been obtained during the progress of the inquiry, it is to be noted that the number of bacteria capable of growing in agar at blood-heat in Crossness crude sewage is usually over three millions per c.c., and more than one-half of the number of microbes growing in gelatine at 20° C. It must be admitted that the 13-foot coke-bed at Crossness yielded very unsatisfactory results from the bacteriological point of view.

* See fig. 5.

Thus although the effluents usually contained fewer bacteria and less of *B. coli* and spores of *B. enteritidis sporogenes* than the crude sewage, the reduction was not well marked, and, indeed, was immaterial from the epidemiological point of view, considering the *actual* number still remaining. For, as has been already pointed out, the effluents usually contained more than one million microbes, more than 100,000 *B. coli*, and at least 100 but less than 1,000 spores of *B. enteritidis sporogenes* per c.c.

IV.—STREPTOCOCCI IN THE BARKING AND CROSSNESS CRUDE SEWAGE AND IN THE EFFLUENTS FROM THE BACTERIAL COKE-BEDS.

In the First Report* under the heading of "Methods" it was stated that streptococci and staphylococci were to be looked for in agar cultures incubated at blood-heat. In the Second Report† when dealing with the "species of micro-organisms" it was noted that streptococci and staphylococci were present both in the crude sewage and in the effluents from the coke-beds. In the present Report it is proposed to give the results of the work carried out in this direction. It is to be noted that the records extend back to November, 1898.

Although attention was directed to the study of staphylococci as well as streptococci it is the latter class of germs which will be considered here. One reason why staphylococci are considered of relatively less importance than streptococci in connection with the work is that the former as a class are hardy germs, whereas the latter as a class are delicate micro-organisms. The bearing of this remark will be shown presently.

My chief reasons for considering this portion of the sewage inquiry of special and peculiar importance are briefly as follows—

Speaking of streptococci as a class it may be said that—

- (1) They are among the most *pathogenic* of all the bacteria which are at present known;
- (2) They are *delicate* germs, and very readily lose their vitality and die;
- (3) They are present in the *intestinal discharges* of animals. In human faeces there may be more than 1,000 present in one gramme;
- (4) They are absent from water and soil,‡ except in those cases where there has been recent contamination with sewage or other substances equally objectionable in character.

It will presently¶ be shown that both in crude sewage and in effluents from coke-beds streptococci are present in great abundance—usually more than 1,000 in 1 c.c.—and that the bacterial treatment of the raw sewage effected no marked alteration in their numbers.

Now if the streptococci found in such numbers in the crude sewage and in the effluents are derived from the intestinal contents of animals, and are delicate germs, and are also pathogenic, the position is a somewhat serious one.

In the first place, as regards *experiments on animals*, the records show that the streptococci were more often non-pathogenic than pathogenic in the case of mice. Numerous records of the effects on mice of streptococci isolated from soil-polluted water, sewage, and sewage effluents which I have since obtained and which are not included in this Report show that as a rule, and when obtained from the above sources, they are not pathogenic. Still it must not be lost sight of that the absence of pathogenic effect on mice does not necessarily imply the absence of disease-producing property in other animals. Nor does it prove that the streptococci were previously non-pathogenic. Further, it is conceivable that some alteration in the conditions surrounding these streptococci might, if they had been pathogenic in the past, restore to them all their original virulence.

Speaking in general terms, however, it may be said that the streptococci found in nature outside the animal body, e.g., in polluted soils and water, in sewage and sewage effluents are not as a rule pathogenic to mice.

Secondly, as regards the assertion that streptococci are *delicate germs* and readily lose their vitality and die. Although this certainly accords with our experience of streptococci isolated from the human subject, particularly in cases of disease and septic infection, it might well be the case that some at all events of the streptococci occurring in nature outside the animal body, e.g., in sewage, are hardy germs and are capable not only of resisting death, but also of multiplying under favourable conditions. In all probability this is true to some extent, yet it is not without significance that certain of the streptococci about to be described when subcultured in gelatine and incubated at 20° C. showed little or no appreciable growth at the end of thirteen days. And some of the streptococci that I have isolated from sewage-polluted water, etc., have proved their delicacy by refusing to grow when subcultures were not carried out at short intervals. Thus on several occasions the study of a streptococcus has been prematurely cut short by the death of the organism. Still further it has been a matter of common observation that subcultures made from colonies in agar plate cultures of sewage which (colonies) under a low power of the microscope revealed their real nature by the occurrence of separate loops of cocci at the periphery, frequently showed *no growth*, the microbes (streptococci) having already lost their vitality. In opposition to this it might be urged that certain of the streptococci in sewage are in reality hardy germs, but that the

* Filtration of sewage (First Report), page 3, B. 6 (e).

† Bacterial treatment of crude sewage (Second Report), page 27, III., 4 (c).

‡ The significance of streptococci in water and soil is dealt with by me in Reports to the Local Government Board. Report of the Medical Officer, Local Government Board, 1898-9.

¶ In this and succeeding paragraphs I purposely anticipate what follows.

nutrient media ordinarily employed by bacteriologists is not the most suitable kind of pabulum for them. It is to be noted as possibly affording some support to this view that if sewage be centrifuged and the deposit stained* the microbes taking the stain are not, as might have been anticipated, chiefly bacillary in form, but appear either as cocci or rods, so short and rounded at their ends as to simulate cocci. Moreover, these cocci are frequently arranged in long chains (streptococci).

Nevertheless, it may be said with a fair measure of confidence that some, at all events, of the streptococci in sewage and in sewage effluents are delicate germs, and readily lose their vitality and die.

The importance to be attached to these observations is great. If in the bacterial treatment of sewage micro-organisms of presumably feeble vitality pass through the coke-beds in practically unaltered numbers, then there is every reason to fear that those microbes which we know are distinctly pathogenic to man, and which may be either habitually present in sewage or present as chance and occasional visitors, and some of which are believed to be in comparison hardy germs, would likewise be unaffected by the biological processes at work in the coke-beds.

In previous Reports I have stated "that the balance of evidence points to the probability that some, at all events, of the pathogenic organisms are crowded out in the struggle for existence in a nutritive medium, containing a mixed bacterial flora, their vitality being weakened or destroyed by the enzymes of the saprophytic species." This broad statement was permissible then, but now, in the light of these results, it can hardly be considered altogether satisfactory.

Lastly, as regards the source of streptococci, it has been said that they are present in the intestinal discharges of animals, and are absent from waters and soils except in cases of recent and objectionable pollution. It might perhaps be argued that streptococci may have a wide distribution in nature, and if so that their presence in a substance, be it soil or sewage or water, is of little or no significance. Against this view it may be pointed out that if they are delicate germs it is unlikely that they would survive, much less multiply in nature unless the conditions were ideally favourable. Further, that although I have frequently isolated streptococci from as minute a quantity of sewage as 0.001 c.c., and of human fæces as 0.001 gramme, I have repeatedly failed to demonstrate their presence in comparatively large amounts of pure water and pure soils.||

These facts have led me to advocate this test (presence of streptococci) as a valuable one in the bacterioscopic examination of waters.† Not, indeed, that the absence of streptococci implies "safety," but that their presence affords strong evidence of recent and therefore presumably specially dangerous pollution.

In conclusion I venture to assert that this test is of extreme value in judging sewage effluents from the biological point of view. And I am strongly of opinion that if an effluent contains streptococci in practically unaltered numbers, or even in reduced numbers where such reduction is only in the same proportion as the other microbes also present are reduced, then such an effluent is, as regards danger to health, no better in the first case than raw sewage and no safer in the latter than crude sewage slightly diluted, but otherwise unaltered in its possible capacity of giving rise to disease.

The following is a description of some of the streptococci isolated from London crude sewage and from the effluents from the bacterial beds.

1. Name—*Streptococcus I.*
2. Source— $\frac{1}{1000}$ c.c., Crossness crude sewage.
3. Date—November 16th, 1898.
4. Morphology—Stains well by Gram's method. The chains of cocci are usually short.
5. Plate cultures (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) Agar (37° C.)—Small transparent colonies showing wavy granulation. The colonies are irregular in shape, and at the edges the loops of cocci can be made out§.
 - (b) Gelatine (20° C.)—Small transparent colonies, circular in shape, and faintly granular. The edges are clean and no loops of cocci are visible. No liquefaction.
6. Streak cultures—
 - (a) Agar (37° C.)—Small transparent colonies, faintly granular.
 - (b) Gelatine (20° C.)—A white, transparent film-like growth, which on close observation is seen to be made up of separate colonies. No liquefaction occurs.
7. Gelatine at 37° C.—No diffuse cloudiness. Flocculent little masses with cirrus-like extensions.¶
8. Broth cultures (37° C.)—The broth remains quite transparent. Flocculent masses with cirrus-like extensions are formed in the fluid. Old broth cultures show at the foot of the tube a white granular mass, the medium itself being quite transparent. On shaking the tube, granular masses of various sizes rise in the clear liquid and rapidly subside again to the bottom.‡
9. Litmus milk cultures (37° C.)—Strong acidity and solid clot in 24 hours.
10. Remarks—A mouse inoculated subcutaneously with 1 c.c. of broth culture remained apparently unaffected.

1. Name—*Streptococcus II.*
2. Source— $\frac{1}{1000}$ c.c., Crossness 6 ft. primary coke-bed effluent.
3. Date—November 16th, 1898.
4. Morphology—Stains well by Gram's method. Very short chains as a rule, but occasionally a chain of medium length may be found.

* Deposit upon the coke in the coke-beds. (Supplement to the Second Report.) See also Plate II., Figs. 6, 7, and 8 of this Report.

|| I have, however, found streptococci in abundance in waters and soils recently polluted with sewage.

† Report of the Medical Officer, Local Government Board, 1898-99.

§ Plate IV., fig. A. (a).

¶ Plate IV., fig. B. (a).

‡ Plate IV., fig. B. (b).

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Small transparent circular faintly-granular colonies with *firm* edges. No loops of cocci are visible at the periphery.*
 - (b) *Gelatine* (20° C.)—Small transparent faintly-granular colonies, circular in shape with *clean* edges. Old colonies may present a nucleated appearance. No appearance of separate loops of cocci at the periphery of the colonies. No liquefaction.†
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—Minute transparent colonies. The colonies are situated so close together as to appear at first sight like a continuous film.
 - (b) *Gelatine* (20° C.)—Almost no growth, even after 13 days.
7. *Gelatine at 37° C.*—Granular cloudiness, with a white granular deposit at the foot of the tube.‡
8. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube white viscous growth, which on shaking the tube, rises in the form of a spiral.§
9. *Litmus milk cultures* (37° C.)—In 2 day's acidity; in 4 days, strong acidity but no clot; 7th day, still no clot; 25th day, still no clot.
10. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. of a 4 days' broth culture died on the 7th day. Microscopic preparations made from the kidney juice showed the presence of cocci, sometimes arranged as diplo-cocci, and showing an appearance as of a surrounding capsule. This was not very distinct, however. Agar plate cultures were made from the spleen, and a streptococcus was isolated, which differed somewhat from the one above described. It produced diffuse cloudiness in broth and diffuse granular cloudiness in gelatine at 37° C. Milk was rendered strongly acid and clotted.

1. *Name*—*Streptococcus III*.
2. *Source*— $\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length; most of them are short.

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Minute transparent faintly-granular colonies. Most of the colonies are circular with a *clean* edge. Some are irregular in shape with a ragged edge resembling somewhat *Streptococcus I*.¶
 - (b) *Gelatine* (20° C.)—Small transparent colonies, roughly circular in shape with firm edges. The colonies are faintly granular, and show no separate loops of cocci at the periphery. No liquefaction.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—The growth appears at first sight like a continuous delicate film, but is in reality composed of numerous minute transparent and separate colonies.
 - (b) *Gelatine* (20° C.)—Colonies are somewhat large for a streptococcus: they are roughly circular in shape, and have a granular appearance. No liquefaction.
7. *Gelatine at 37° C.*—Granular cloudiness at the foot of the tube. Throughout the medium granular cloudiness and slight diffuse cloudiness as well.
8. *Broth cultures* (37° C.)—Diffuse cloudiness throughout the medium.
9. *Litmus milk cultures*—Acidity, but no clot in 24 hours. Later, strong acid but no clot (14th day).
10. *Remarks*—1 c.c. of a 2 days' broth culture injected subcutaneously in a mouse produced no apparent effect.

1. *Name*—*Streptococcus IV*.
2. *Source*— $\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains by Gram's method. Chains of cocci of variable length; usually short, however.

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Colonies very similar to *Streptococcus III*.
 - (b) *Gelatine* (20° C.)—As practically no growth occurred in gelatine streak cultures, no gelatine plates were made.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—Growth resembles both *Streptococcus I*. and *Streptococcus III*.
 - (b) *Gelatine* (20° C.)—Practically no growth, even after 13 days.
7. *Gelatine at 37° C.*—Granular deposit at foot of tube and granular cloudiness throughout the medium, but no diffuse cloudiness.||
8. *Broth cultures* (37° C.)—Diffuse cloudiness. Deposit at the foot of the tube coherent in masses unlike *Streptococcus III*.
9. *Litmus milk cultures* (37° C.)—Distinct acidity, but no clot (11th day).
10. *Remarks*—1 c.c. of a 2 days' broth culture injected subcutaneously in a mouse. The mouse died on 9th day. Cover glass specimens made from kidney juice, peritoneal fluid, &c., showed the presence of cocci and diplococci (appearance suggestive of surrounding capsule, but not very distinct). Agar plate cultures were made from the organs, but the plates were crowded with putrefactive bacteria, and no streptococci were isolated.

1. *Name*—*Streptococcus V*.
2. *Source*— $\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains by Gram's method. Short chains and chains of medium length.

* Plate IV., fig. A (b). † Plate IV., fig. A (c). ‡ Plate IV., fig. B (c). § Plate IV., fig. B (d).
 ¶ Plate IV., fig. A (d). || Plate IV., fig. B (e)

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Appearances very similar to *Streptococcus* III., *i.e.*, some colonies circular and granular with *clean* edges; others more or less irregular in shape with ragged edges. Apparently, however, fewer colonies of irregular shape and ragged edges than in the cases of *Streptococci* III. and IV.
 - (b) *Gelatine* (20° C.)—As there was practically no growth in gelatine streak cultures, no gelatine plate cultures were made.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—Growth somewhat similar in appearance to *Streptococcus* III.
 - (b) *Gelatine* (20° C.)—Practically no growth (13th day).
7. *Gelatine at 37° C.*—Appearance very like *Streptococcus* III.
8. *Broth cultures* (37° C.)—Diffuse cloudiness.
9. *Litmus milk cultures*—Distinct acidity, but no clot (11th day).

1. *Name*—*Streptococcus* VI.
2. *Source*—1000 c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length, but usually short.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Small transparent granular colonies, usually circular in shape. Most of the colonies have a firm edge, but in some of them the edge has a ragged appearance.
 - (b) *Gelatine* (20° C.)—No record.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—The growth resembles *Streptococcus* I.
 - (b) *Gelatine* (20° C.)—By the 13th day the colonies have attained a fair size: they are granular, and at the edge have a lobed and fissured appearance. The colonies are white, but towards the centre they are yellowish-white in colour. No liquefaction.
7. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube white viscous growth, which on shaking the tube rises in the form of a spiral.
8. *Litmus milk cultures* (37° C.)—Very slight acidity, no clot (10th day).

1. *Name*—*Streptococcus* VII.
2. *Source*—1000 c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length, but usually short.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Small more or less circular colonies, transparent and granular. Most of the colonies have a firm edge, but in others the edge is broken up and uneven in character.
 - (b) *Gelatine* (20° C.)—As there was practically no growth in gelatine streak cultures (13th day at 20° C.), no gelatine plate cultures were made.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—No record.
 - (b) *Gelatine* (20° C.)—Practically no growth (13th day at 20° C.).
7. *Broth cultures* (37° C.)—Some diffuse cloudiness, and at the foot of the tube granular masses as in *Streptococcus* I.
8. *Litmus milk cultures* (37° C.)—Slight acidity, but no clot (10th day).

1. *Name*—*Streptococcus* VIII.
2. *Source*—1000 c.c., effluent from 6 ft. primary coke-bed at Crossness.
3. *Date*—December 9th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length.
5. *Agar plate cultures* (37° C.) (under a low power, Leitz, 3 objective, 1 ocular)—Small transparent granular colonies with firm edges and roughly circular in shape.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—The growth appears as a thin transparent greyish-white film, which on close examination is seen to be made up of minute separate colonies.
 - (b) *Gelatine* (20° C.)—Colonies are transparent and granular-looking. No liquefaction (13th day).
7. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube a white deposit, which rises in the form of a spiral on shaking the tube.
8. *Litmus milk cultures* (37° C.)—Strong acidity, but no clot (11th day).
9. *Remarks*—1 c.c. of broth culture injected subcutaneously into a guinea-pig. The animal remained apparently unaffected.

1. *Name*—*Streptococcus* IX.
2. *Source*—1000 c.c., effluent from 6 ft. secondary coke-bed at Crossness.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci usually short, but some of medium length.
5. *Agar plate cultures*, 37° C. (under a low power, Leitz, 3 objective, 1 ocular)—The majority of the colonies are circular in shape with firm edges. They are small, granular and transparent looking.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—The growth at first sight looks like a continuous white film, but on close inspection it is seen to be made up of numerous separate minute transparent colonies.
 - (b) *Gelatine* (20° C.)—Minute transparent colonies, more or less circular in shape. No liquefaction.

7. *Broth cultures* (37° C.)—Diffuse cloudiness; white deposit, at the foot of the tube; on shaking the tube deposit rises in the form of a spiral.

8. *Litmus milk cultures* (37° C.)—Feeble acidity in two days. Later, distinct acidity, but no clot (11th day).

9. *Remarks*—1 c.c. of a 24 hours' (at 37° C.) broth culture injected subcutaneously in a mouse. The mouse died on the 5th day. Cocci present in juice of spleen and kidneys. From the spleen a pure culture of a streptococcus was obtained, forming chains of medium length, and which differed somewhat from the above. In broth the fluid remained clear, and at the foot of the tube the growth occurred as a white conglomerate mass. In gelatine at 37° C. very slight diffuse cloudiness, and at the foot of tube a loose flocculent cloudy growth. In gelatine plate cultures, colonies irregular in shape with uneven edge, wavy granulation well marked.

1. *Name*—*Streptococcus X*.

2. *Source*— $\frac{1}{1000}$ c.c., effluent from 6 ft. secondary coke-bed at Crossness.

3. *Date*—December 15th, 1898.

4. *Morphology*—Stains well by Gram's method. Chains of cocci of medium length.*

5. *Agar plate culture*, 37° C. (under a low power, Leitz, 3 objective, 1 ocular)—Irregularly-shaped colonies with broken up edge. Transparent with wavy granulation, and at edge loops of cocci can be made out.†

6. *Streak cultures*—

(a) *Agar* (37° C.)—The growth is made up of numerous minute separate transparent colonies which at first sight appears like a continuous filmy growth.

(b) *Gelatine* (20° C.)—By the 13th day colonies of varying size. They are very irregular in shape, with lobed and fissured borders and delicate filamentous extensions like fine seaweed. The colonies are white, but towards centre the colour is yellowish-white.

7. *Broth cultures* (37° C.)—Diffuse cloudiness; at foot of tube white viscous deposit which on shaking the tube rises in spiral form.

8. *Litmus milk cultures* (37° C.)—In two days distinct acidity, but no clot; 11th day still no clot.

1. *Name*—*Streptococcus XI*.

2. *Source*— $\frac{1}{1000}$ c.c., Crossness crude sewage.

3. *Date*—December 15th, 1898.

4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length, but usually short.

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—

(a) *Agar* (37° C.)—Most of the colonies minute, transparent and granular with firm edge.

(b) *Gelatine* (20° C.)—The majority of the colonies are nearly circular in shape: they are transparent looking and faintly granular with firm edge. No liquefaction.§

6. *Streak cultures*—

(a) *Agar* (37° C.)—The growth at first sight appears like a continuous film, but is really made up of separate minute transparent colonies.

(b) *Gelatine* (20° C.)—Small transparent faintly granular colonies. No liquefaction (13th day).

7. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube viscous white deposit, which on shaking the tube rises in the form of a spiral.

8. *Litmus milk cultures* (37° C.)—No visible change, even after 11 days' incubation.

1. *Name*—*Streptococcus XII*.

2. *Source*— $\frac{1}{1000}$ c.c., Crossness crude sewage.

3. *Date*—December 15th, 1898.

4. *Morphology*—Stains well by Gram's method. A streptococcus forming very short chains.

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—

(a) *Agar* (37° C.)—Small circular colonies with firm edge, transparent and granular looking.

(b) *Gelatine* (20° C.)—The colonies are usually circular: they are faintly granular and transparent looking. The edge is clean. No liquefaction.¶

6. *Streak cultures*—

(a) *Agar* (37° C.)—The colonies are rather large for a streptococcus; they have a granular and transparent appearance.

(b) *Gelatine* (20° C.)—The mass of the growth appears as a continuous film; but at the edge and upper portion of the streak the colonies are separate and are small with a granular transparent appearance. No liquefaction.

7. *Gelatine at 37° C.*—A granular white deposit forms at the foot of the tube, and the gelatine throughout is full of minute granular specks.

8. *Broth cultures* (37° C.)—The broth is clear, but on sides of tube white cirrus-like growth, and at foot of tube viscous white conglomerate mass.

9. *Litmus milk cultures* (37° C.)—Slight acidity, but no clot (11th day).

1. *Name*—*Streptococcus XIII*.

2. *Source*— $\frac{1}{1000}$ c.c., Crossness crude sewage.

3. *Date*—December 15th, 1898.

4. *Morphology*—Stains well by Gram's method. It was difficult to determine whether this microbe was a streptococcus or a staphylococcus. Finally, it was classed as a streptococcus.

* Plate I., fig. 1.

† Plate IV., fig. A (e).

§ Plate IV., fig. A (f).

¶ Plate IV., fig. A (g).

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—The large colonies are roughly circular in shape and the smaller ones irregular. Wavy granulation is well marked, and at the edge of the colonies separate loops of cocci can be made out. The colonies are small and transparent-looking.*
 - (b) *Gelatine* (20° C.)—The colonies are very irregular in shape, and at the edge loops of cocci may be made out. They are small and transparent, and show a coarse wavy granulation.†
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—The growth is composed of separate colonies which are transparent and granular-looking, and are rather large for a streptococcus.
 - (b) *Gelatine* (20° C.)—By the 13th day the colonies have attained a fair size; they are irregular in shape and tend to run into each other. No liquefaction.
7. *Gelatine at 37° C.*—Resemble Streptococcus XII.
8. *Broth cultures* (37° C.)—The cloudiness is not well marked and is somewhat granular in character. On shaking the tube gently viscous white masses with cirrus-like extensions rise from the foot and float throughout the liquid.
9. *Litmus milk cultures* (37° C.)—Slight acidity, but no clot (15th day).
10. *Potato cultures* (37° C.)—No visible growth (8th day).

1. *Name*—Streptococcus XIV.
2. *Source*— $\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. The chains are short and tend to cohere in masses. The cells are somewhat irregular in shape.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—The colonies are small, nearly circular in shape, with a fairly firm edge. They are granular and transparent-looking.
 - (b) *Gelatine* (20° C.)—The colonies are roughly circular in shape. Wavy granulation is well marked. The edge may have a slightly ragged appearance, but no separate loops of cocci can be made out. No liquefaction.§
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—The colonies are separate, granular and transparent-looking, but are of rather a large size for a streptococcus.
 - (b) *Gelatine* (20° C.)—Resembles Streptococcus XII. No liquefaction (13th day).
7. *Gelatine at 37° C.*—Resembles Streptococcus XII.
8. *Broth cultures* (37° C.)—The broth remains nearly transparent. At the foot of the tube the growth collects as a viscous white mass.
9. *Litmus milk cultures* (37° C.)—Distinct acidity, but no clot (11th day).

1. *Name*—Streptococcus XV.
2. *Source*— $\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci are usually short, but some are of medium length.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Small, transparent, circular, granular colonies with firm edge.
 - (b) *Gelatine* (20° C.)—Small colonies of circular shape and with clean edge. They may present a nucleated appearance. They are granular and transparent-looking. No liquefaction.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—A barely visible white film, which on close observation is seen to be made up of separate colonies (minute and transparent-looking).
 - (b) *Gelatine* (20° C.)—Resembles somewhat Streptococcus XII. No liquefaction (13th day).
7. *Broth cultures* (37° C.)—Diffuse cloudiness. At the foot of the tube a white viscous deposit, which on shaking the tube rises in the form of a spiral.
8. *Litmus milk cultures* (37° C.)—In two days, distinct acid but no clot; 5th day, ditto; 11th day, ditto.
9. *Remarks*—1 c.c. of a 24 hours' broth culture (37° C.) injected subcutaneously into a mouse. The mouse died on the 5th day. Microscopic preparations were made from the peritoneal fluid, &c. Cocci were present, but also many putrefactive bacilli. Agar plates made from the spleen were overgrown with putrefactive organisms, and no streptococci could be isolated.

1. *Name*—Streptococcus XVI.
2. *Source*— $\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Long chains of cocci matted together in masses.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Minute transparent colonies, usually of circular shape, and showing wavy granulation. No separate loops of cocci at periphery.
 - (b) *Gelatine* (20° C.)—Small, circular, transparent and granular-looking colonies. No liquefaction.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—Thin, delicate film, which on close examination is seen to be made up of minute separate colonies.
 - (b) *Gelatine* (20° C.)—Resembles Streptococcus X.
7. *Broth cultures* (37° C.)—Broth remains perfectly transparent. At foot of tube white conglomerate mass.
8. *Litmus milk cultures* (37° C.)—Second day, no visible change; 5th day, slight acidity, but no clot. Later, acidity more decided. No clot 11th day.

* Plate IV., fig. A (h).

† Plate IV., fig. A (i).

§ Plate IV., fig. A (j).

1. *Name*—*Streptococcus XVII*.
2. *Source*— $\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci short. The cells tend to cohere in masses simulating a staphylococcus.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Small, granular and transparent-looking colonies, nearly circular in shape. The edge of the colonies has a ragged appearance, but no separate loops of cocci can be made out.
 - (b) *Gelatine* (20° C.)—Minute colonies of circular shape, showing faint granulation. The colonies are transparent-looking and some have a nucleated appearance. The edge is firm and no separate loops of cocci are visible. No liquefaction.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—The growth presents no special characters worthy of note.
 - (b) *Gelatine* (20° C.)—Resembles somewhat *Streptococcus XII*. No liquefaction.
7. *Broth cultures* (37° C.)—Broth remains quite transparent. On sides of tube cirrhous-like, streaky, white growth. At foot of tube, viscous white deposit.*
8. *Litmus milk cultures* (37° C.)—In two days, distinct acid, but no clot; 5th day, ditto; 11th day, ditto.

1. *Name*—*Streptococcus XVIII*.
2. *Source*— $\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Short to medium chains.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Colonies circular with firm edge; transparent and faintly granular.
 - (b) *Gelatine* (20° C.)—Most of the colonies seem to be made up of two portions, a granular, irregularly-shaped, darker portion, and a more transparent and larger portion, which is less granular. Some of the colonies, however, appeared to be composed of a collection of delicate loops like *S. Longus* type. No liquefaction.†
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—Resembles somewhat *Streptococcus XV*.
 - (b) *Gelatine* (20° C.)—On the 13th day the growth resembled *Streptococcus XII*., but in a few places delicate filamentous extensions like fine seaweed may be seen. No liquefaction.
7. *Broth cultures* (37° C.)—Diffuse cloudiness, and at foot of tube viscous white deposit, which on shaking the tube rises in the form of a spiral.
8. *Litmus milk cultures*—No visible change, even after 11 days' incubation.

1. *Name*—*Streptococcus XIX*.
2. *Source*— $\frac{1}{1000}$ c.c., effluent from the primary coarse bed (series A) at Barking.
3. *Date*—November 1st, 1899.
4. *Morphology*—Stains well by Gram's method. The chains of cocci are of medium length.§
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Irregularly-shaped, transparent colonies, showing well-marked wavy granulation. At the edge of some of the colonies separate loops of cocci are clearly visible.
 - (b) *Gelatine* (20° C.)—Small transparent colonies, showing faint wavy granulation. Usually circular in shape with clean edge. No liquefaction.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—No record.
 - (b) *Gelatine* (20° C.)—Minute, transparent, circular colonies. No liquefaction.
7. *Broth cultures* (37° C.)—Some diffuse cloudiness, but granular cloudiness as well. On sides of tube, streaky, cirrhous-like, white growth.
8. *Litmus milk cultures* (37° C.)—In two days strong acid, but no clot; 4th day, ditto.
9. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. broth culture remained apparently unaffected.

1. *Name*—*Streptococcus XX*.
2. *Source*— $\frac{1}{1000}$ c.c., effluent from the secondary coarse bed (series A) at Barking.
3. *Date*—November 1st, 1899.
4. *Morphology*—Stains well by Gram's method. Resembles *Streptococcus XIX*.¶
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Minute, transparent colonies, nearly circular in shape with clean edge. Wavy granulation very faint. Some of the colonies are more granular-looking and have a slightly frayed edge.
 - (b) *Gelatine* (20° C.)—Resembles *Streptococcus XIX*.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—No record.
 - (b) *Gelatine* (20° C.)—Very similar to *Streptococcus XIX*., but the colonies are more transparent-looking.
7. *Broth cultures* (37° C.)—Resembles *Streptococcus XIX*.
8. *Litmus milk cultures*—In two days, strong acid but no clot; 4th day, strong acid but no clot.
9. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. of a broth culture was apparently unaffected.

* Plate IV., fig. B (f).
§ Plate I., fig. 2.

† Plate IV., fig. A (k).
¶ Plate I., fig. 3.

1. *Name*—*Streptococcus* XXI.
2. *Source*— $\frac{1}{1000}$ c.c., Barking crude sewage.
3. *Date*—November 1st, 1899.
4. *Morphology*—Stains well by Gram's method. The chains of cocci are usually short, but occasionally long chains may be seen.*
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
 - (a) *Agar* (37° C.)—Minute, transparent, faintly granular-looking colonies with clean edge. Usually circular in shape.
 - (b) *Gelatine* (20° C.)—Small transparent colonies showing only very faint granulation. Colonies are circular with slightly wavy border. No liquefaction.
6. *Streak cultures*—
 - (a) *Agar* (37° C.)—No record.
 - (b) *Gelatine* (20° C.)—Resembles *Streptococcus* XIX. and XX., but the colonies are smaller and more transparent-looking.
7. *Broth cultures* (37° C.)—Abundant diffuse cloudiness; at foot of tube viscous white deposit.
8. *Litmus milk cultures* (37° C.)—Strong acidity, but no clot.
9. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. of broth culture was apparently unaffected.

GENERAL SUMMARY OF THE ABOVE RESULTS, AS REGARDS THE PRESENCE OF STREPTOCOCCI IN THE CRUDE SEWAGE AND IN THE EFFLUENTS FROM THE BACTERIAL BEDS.

Name—It is apparent that many of the streptococci resembled *S. Brevis* and some *S. Longus*. Moreover, certain of them, if they had been isolated from a septic case in the human subject, would almost certainly have been classed as *S. Pyogenes*. In the present state of our knowledge, it has been thought best to merely register them for descriptive purposes as *Streptococcus* I., II., III., &c. Of course, many of them resembled each other so closely as to suggest identity of species or, at all events, close kinship. But the results seem to indicate that streptococci are not only more numerous, but that the number of different species is much greater than has hitherto been supposed. A great many microbes isolated from crude sewage and effluents from bacterial beds are not included in the above list, because, on studying their morphological and biological characters, they seemed to resemble staphylococci (a class of germs as numerous in sewage apparently as streptococci, but probably of relatively less importance) more closely than streptococci. The line, however, dividing these two classes of germs is by no means a sharp one, and it is possible that a few microbes have been included in the above list which really ought to be placed in an intermediate position, *i.e.*, between the streptococci and staphylococci.

Source—In each case the streptococci were isolated from as minute a quantity as $\frac{1}{1000}$ c.c. of Barking or Crossness crude sewage, or the effluents from the coke-beds at Barking and Crossness. There did not appear to be any significant alteration in the number of streptococci as the result of the bacterial treatment of the raw sewage.

Date—It is to be noted that the earlier records extend back as far as November, 1898.

Morphology—All stained well by Gram's method. The majority formed short chains, but in some the chains were of medium length, and in a few the chains were long. Sometimes the chains cohered together forming masses, thus simulating staphylococci. In such cases the biological characters of the microbes were closely studied before coming to a definite conclusion. [As a rule staphylococci grow more rapidly and produce a much more luxuriant and opaque growth on the surface of gelatine and agar than streptococci. Further, staphylococci not uncommonly liquefy gelatine. On the other hand, streptococci do not liquefy gelatine, and as a rule grow very slowly and form minute and transparent-looking colonies in agar and gelatine cultures.]

Temperature—It is to be noted that all the streptococci grew well at blood heat.

Agar and gelatine cultures—In most cases the colonies were very small, circular in shape, transparent-looking, and faintly granular, with a *clean* edge. Sometimes, however, the colonies showed coarse, wavy granulation, and were irregular in shape with a frayed edge, or showed at the periphery separate loops of cocci. It must not be lost sight of that some of the streptococci showed little or no appreciable growth when incubated at 20° C. for 13 days in gelatine streak culture.

Broth cultures—About 50 per cent. produced diffuse cloudiness with a viscous white deposit at the foot of the tube. In about 20 per cent. the broth remained quite clear, the growth appearing either as a conglomerate mass or else as masses with cirrhous-like extensions. In about 15 per cent. the cloudiness was granular in character with streaky cirrhous-like growths. In about 10 per cent. there was diffuse cloudiness

with a deposit at the foot of the tube coherent in granular masses. In about 5 per cent. a viscous white mass collected at the foot of the tube, the broth remaining transparent.

Litmus milk cultures—About 85 per cent. produced acidity but no clot. About 5 per cent. showed acidity and clot. About 10 per cent. produced no visible change.

Experiments on animals—Only a limited number of experiments were carried out. Sometimes a pathogenic effect was produced in mice, but most of the animals were apparently unaffected. An absence of pathogenic effect as regards mice does not necessarily imply freedom from disease-producing capability in respect of other animals. Moreover, some of these streptococci may have been highly virulent in the past, but have lost their pathogenic action. It is conceivable that these same streptococci might under certain conditions regain their full virulence.

It is apparent from these results that the type of streptococcus which is especially abundant in sewage is one presenting the following characters. For convenience of description it is permissible to call this microbe "*Sewage Streptococcus*." The following is a brief description of its chief morphological and biological characters —

1. *Name*—" *Sewage Streptococcus*."
2. *Source*—Barking and Crossness crude sewage and effluents from bacterial coke-beds.
3. *Abundance*—Usually more than 1,000 per c.c. of crude sewage and effluents.
4. *Temperature*—Grows well at blood heat.
5. *Morphology*—Stains well by Gram's method. The chains of cocci are usually short.
6. *Agar and gelatine plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—The colonies are small and transparent. They are nearly circular in shape with a *clean* edge. The granulation is faint. The colonies in agar are usually more granular and darker looking than in gelatine cultures. The gelatine is not liquefied.
7. *Streak cultures* (agar at 37° C. and gelatine at 20° C.)—The growth usually shows itself as a delicate white film, which on close observation is seen to be made up of numerous separate minute transparent-looking colonies. The gelatine is not liquefied.
8. *Broth cultures* (37° C.)—Abundant diffuse cloudiness. On gently shaking the tube a viscous white deposit rises from the foot of the tube in a spiral form.
9. *Litmus milk cultures* (37° C.)—Acidity, but usually no clot.
10. *Remarks*—Probably non-pathogenic to mice.

It will be understood that the above is a description not of a special micro-organism, but of the type of streptococcus most commonly present in crude sewage and in the effluents from the coke-beds.

V.—EXPERIMENTS ON ANIMALS.

INJECTION OF CRUDE SEWAGE AND EFFLUENTS INTO GUINEA-PIGS.

The conclusions which have been arrived at as a result of the above experiments may be briefly stated as follows:—

I.—The subcutaneous injection of Barking and Crossness crude sewage into guinea-pigs (about 1—3 c.c. per 200 grammes weight) always produces a local reaction, and usually death in from 24 to 72 hours. If the guinea-pigs do not die within the first few days, although suppuration and ulceration may set in at the site of the inoculation, the animal usually eventually recovers completely. Sometimes the effluents from the coke-beds are more pathogenic than the raw sewage itself, but as a rule a somewhat larger dose of effluent is required to produce a fatal result. If the crude sewage or effluent be injected intra-peritoneally instead of subcutaneously, the animals usually die more quickly, and succumb to a smaller dose. There are, however, exceptions to this rule.

II.—If the injection of the crude sewage or effluent is not followed by fatal results within the first few days, the animal may occasionally die after the lapse of some weeks time, and on post-mortem examination show appearances simulating tubercle infection; but on closer study it will be found that death was really due to *pseudo-tuberculosis* (*B. pseudo-tuberculosis* of Pfeiffer).

[It will be remembered, however, that in one case a guinea-pig inoculated with a portion of coke-deposit died from *true tuberculosis*. Supplement to Second Report.]

III.—When the animal dies rapidly (24—72 hours), virulent microbes, belonging to the class of *B. coli* and *B. proteus*, may readily be isolated from the blood or tissues of the animal.

IV.—If the crude sewage or effluent be previously heated to 100° C. for one hour, large doses may be injected without producing a fatal result. This would seem to show that the pathogenic effect of the sewage and effluents is not directly traceable to such of the intra-cellular and extra-cellular products of microbes as are capable of resisting this temperature.

[This temperature (100° C.) would change poisonous *active albuminoids* to non-poisonous *passive albuminoids*, and would also decompose *enzymes*; but it would not destroy the poisonous substances resulting from the decomposition of putrefying albuminoids known as *ptomaines*.]

V.—If the crude sewage or effluent be previously heated to 80° C. for ten minutes, a pathogenic effect may still be produced; but a much larger dose is usually required than where the liquid has not been so heated. Here death, when it occurs, is probably due to *B. enteritidis*.

sporogenes, or, it may be, to anaërobic micro-organisms of the *malignant œdema* group. These results would seem to indicate that the pathogenic effect of sewage and sewage effluents is not usually or primarily due to micro-organisms present in spore form, since a much larger dose is required when the liquid has been previously heated to 80° C.; unless, indeed, these microbes possess an increased pathogenic power in the presence of other germs not present as spores.

VI.—If the crude sewage or effluent be filtered through a sterilised Pasteur's filter, very large doses of the filtrate fail to produce a pathogenic effect. This would seem to prove that it is not the extra-cellular products of the bacteria which by themselves produce the pathogenic result. But it is conceivable that filtration under the above conditions may render the bacterial products harmless where before they were noxious.

It is not proposed to give in detail the numerous experiments which have been carried out on animals; but a few experiments may be given by way of illustration.

February 22nd, 1899.

- (a) 1 c.c. Barking crude sewage injected subcutaneously in guinea-pig (called g.p. i).
- (b) 1 c.c. effluent from Barking fine ragstone-bed injected subcutaneously in guinea-pig (called g.p. ii).
- (c) 1 c.c. effluent from Barking fine coke-bed injected subcutaneously in guinea-pig (called g.p. iii).

February 23rd—g.p. i poorly, with swollen belly; g.p. ii and iii fairly lively, with less abdominal swelling.

February 24th—g.p. i, moribund; g.p. ii and iii, in about the same condition as on the preceding day.

February 25th—g.p. i dead. On *post-mortem examination*, showed thickening of abdominal wall and œdema, but not much sanguineous exudation.

March 1st—g.p. ii and iii quite lively and well, except that g.p. ii had some abdominal ulceration.

The animals (g.p. ii and iii) eventually recovered completely from the effects of the injection.

March 1st, 1899.

- (a) 1 c.c. Crossness crude sewage injected intra-peritoneally in guinea-pig (called g.p. i).
- (b) 1 c.c. Crossness effluent from B single coke-bed injected intra-peritoneally in guinea-pig (called g.p. ii).

March 2nd—g.p. ii moribund, so killed.

March 3rd—g.p. i dead.

March 29th, 1899.

- (a) 1 c.c. Barking effluent coarse ragstone-bed injected subcutaneously in guinea-pig (called g.p. i).
- (b) 1 c.c. Barking effluent coarse coke-bed injected subcutaneously in guinea-pig (called g.p. ii).
- (c) 1 c.c. Barking effluent fine ragstone-bed injected subcutaneously in guinea-pig (called g.p. iii).
- (d) 1 c.c. Barking effluent fine coke-bed injected subcutaneously in guinea-pig (called g.p. iv).
- (e) 1 c.c. Crossness effluent 13 ft. coke-bed injected subcutaneously in guinea-pig (called g.p. v).

April 1st—g.p. i and g.p. iv dead.

April 3rd—g.p. iii dead.

April 4th—g.p. ii and g.p. v apparently quite recovered from effects of the inoculation.

April 27th, 1899.

- (a) 1 c.c. Crossness crude sewage injected subcutaneously in guinea-pig (called g.p. i).
- (b) 1 c.c. Crossness effluent from 13 ft. coke-bed injected intra-peritoneally in guinea-pig (called g.p. ii).
- (c) 1 c.c. Crossness crude sewage injected intra-peritoneally in guinea-pig (called g.p. iii).
- (d) 1 c.c. Crossness effluent from 13 ft. coke-bed injected subcutaneously in guinea-pig (called g.p. iv).

April 29th—g.p. i dead.

May 1st—g.p. iii dead.

May 4th—g.p. iv dead, g.p. ii apparently quite recovered from the effects of injection.

November 28th, 1899.

- (a) Barking effluent from B 1 coke-bed, heated 80° C. for ten minutes. Two c.c. injected subcutaneously in guinea-pig (called g.p. i). The animal remained apparently unaffected.

December 1st, 1899.

- (a) 3 c.c. Barking crude sewage injected subcutaneously in guinea-pig (called g.p. i).
 - (b) Same as (a), but crude sewage previously heated to 80° C. for ten minutes (called g.p. ii).
- The dose was apparently too large, as both g.p. i and g.p. ii died, but the former died first.

December 12th, 1899.

- (a) 1 c.c. Barking crude sewage injected subcutaneously in guinea-pig (called g.p. i).
- (b) Same as (a), but sewage previously heated to 80° C. for ten minutes, and 2 c.c. injected (called g.p. ii).
- (c) Same as (a), but sewage previously heated to 100° C. for one hour, and 4 c.c. injected (called g.p. iii).
- (d) Same as (a), but sewage first filtered through a sterilised Pasteur's filter, and 10 c.c. of the filtrate injected.

All the animals recovered from the effects of the injection except g.p. i.

VI.—FINAL CONCLUSIONS.

Before giving the final conclusions from the biological point of view as to the value of the bacterial process in use at Barking and Crossness for treating London crude sewage, it is essential to first make some remarks of a general and introductory character; otherwise a totally erroneous impression might be formed, and it might even be considered that the conclusions arrived at after two years' close study of the subject were of such a nature as to condemn the process. Thus, if no note were taken of the chemical results and the practical side of the question and the bacteriological results were considered by themselves, and not read as they ought to be side by side with the chemical data, an impression might be gained which was not intended, and which was quite remote from the truth.

Many of the points about to be alluded to have been dealt with in previous Reports, but it is necessary to repeat them here for the reasons which have been stated.

I.—GENERAL CONCLUSIONS.

The Thames is a tidal river, and the "intakes" for waterworks purposes are situated high up the river and are "cut off" by "locks" from the influence of the sewage discharge at the Outfall Works.*

Although the bulk of London sewage is certainly very great the large size of the river Thames must also be considered, as also the proximity of the "Outfalls" to the sea and the huge body of water in the river at high tide.

The river water outside the influence of the discharges at the Outfall Works is already polluted and contains practically all the bacteria found in raw sewage.

The body of Thames water which may be supposed to be directly affected by the discharge of the effluents at Barking and Crossness is "brackish" and so could hardly be tolerated for drinking purposes even by individuals who are indifferent to the physical characters and biological composition of the water which they drink.

The bacterial coke-beds effect a reduction of at least 50, and it may be as much as 80 per cent. in the amount of dissolved oxidisable and putrescible organic matter in the raw sewage, as compared with 17 per cent. effected by the chemical treatment.

The effluents from the coke-beds are apparently non-putrescible.‡

The suspended matters† in the crude sewage are practically entirely removed as a result of the biological treatment instead of only about 80 per cent. effected by the chemical treatment. And recent experiments seem to show that this result may be obtained without loss of capacity in the coke-beds if the sewage has undergone a previous process of rapid sedimentation.

In the biological treatment no chemicals are required, and no offensive sludge is produced.¶

Where an effluent is turned into a stream to be used for drinking purposes, the bacteriological results are manifestly of more importance than the chemical; but when, as in the present case, the river is not a potable one, and is already polluted, the converse probably holds good; i.e., the chemical state of the effluent is of primary, and the biological of secondary importance. In the first case the chief object is to guard against disease, and in the second case the main consideration is to avoid fouling the river with putrescible matters to such an extent as to constitute a grave public nuisance.

However desirable it may be to obtain an effluent chemically pure, and, at the same time, bacteriologically above suspicion of danger, a process which leads to the solution of the great mass of suspended matters in the raw sewage, which effects a striking reduction in the amount of putrescible matters, which avoids the use of chemicals and the accumulation of offensive sludge, which yields an apparently non-putrescible effluent, and which is at the same time practicable, is one which presents such singular advantages over chemical treatment, and which produces such satisfactory results in view of all the requirements of the case, that it would be idle to deny its value or attempt to minimise its usefulness simply because it falls short of a standard of absolute perfection.

Passing next to considerations which are purely biological in character, the following points are worthy of note.

* It is assumed that no contamination of the *underground water* in the Thames valley takes place as a result of the pollution in the lower *reaches* of the river affecting distant sources of water supply (e.g., deep wells). If in the future reliable evidence to the contrary should be forthcoming, then the whole question might require reconsideration.

† It may be suggested that further evidence is required to show that an effluent apparently non-putrescible remains so under all conditions, and also that an effluent free, or nearly so, from suspended matter remains permanently in that condition. For it is conceivable that an effluent non-putrescible in itself might yet give rise to a putrescent effect when discharged into a stream, and that substances originally in solution might pass out of solution as the result, perhaps, of secondary degeneration. Nevertheless, from actual experiments carried out by the chemists in charge at the Outfall Works, as well as by observation of the state of the river, this would not seem to take place in the case of the discharge of the effluents at Barking and Crossness into the Thames.

¶ As regards this paragraph and the preceding ones, the Second Report (Division 1, Section 1, No. 5, page 7) may with advantage be consulted.

2.—BIOLOGICAL CONCLUSIONS.

Although the total number of bacteria, the number of spores of aerobic bacteria, the number of liquefying microbes, the number of *B. coli* and of spores of *B. enteritidis sporogenes* was, on an average, less in the effluents from the coke-beds than in the corresponding samples of crude sewage, the reduction was not well marked, and in some cases the effluents contained more micro-organisms than the sewage before treatment. Thus, while the chemical results were always satisfactory, the bacteriological results were usually quite the reverse, because the microbes producing the chemical changes passed through the coke-beds in practically unaltered numbers.

[The reasons for this state of things would seem to be that the process itself depends for its success on the vital activity of bacteria; that the fragments of coke are not fine enough to allow of the mechanical separation of the germs; that the products of the growth of the microbes, while they are self-injurious, are not sufficiently poisonous to destroy their life, although they, doubtless, exercise a restraining influence on the extent of the multiplication; and finally, that purification is not carried sufficiently far to exhaust all the assimilable pabulum in the liquid.]

It has been pointed out in previous Reports that *B. coli* is an aerobic facultative anaerobic microbe of intestinal origin which may be pathogenic, and that *B. enteritidis sporogenes* (Klein) is a pathogenic anaerobe typical of excremental matters which appears to be causally related to certain cases of acute diarrhoea in the human subject, and whose cultures are extremely virulent to guinea-pigs.

Both in this and in previous Reports it has been stated that *B. coli* and the spores of *B. enteritidis sporogenes* are present in the effluents from the coke-beds in numbers usually exceeding 100,000 and 100 respectively per c.c. Further, it has been shown that a *proteus-like* germ ("*sewage proteus*") is present in abundance in the effluents—usually more than 100,000 per c.c. Some strains of this microbe are very virulent to guinea-pigs. Lastly, a highly virulent strain of *B. pyocaneus* has been isolated from so minute an amount as $\frac{1}{1000}$ c.c. of a Barking coke-bed effluent.

Further, the cultures made from the crude sewage and effluents were frequently compared side by side, yet no distinct differences could be made out between the two sets of cultures as regards the species of microbes.

[Of course this does not preclude the possibility of there having been a failure to detect points of difference not easily appreciable even to the trained observer. Still less does it mean that no selective process was in operation in the coke-beds. It is known that certain microbes, e.g., the nitrifying germs, do not grow on the media ordinarily used by bacteriologists; and no doubt, as time goes on, the list will be greatly increased. The mere fact that the raw sewage contained little or no oxidised nitrogen while the effluents contained nitrites and nitrates, implies that nitrification was in progress, and doubtless the nitrifying germs were not only stored in the coke-beds, but were present in the effluents in greater number than in the raw sewage. Indeed, certain experiments which were carried out in this connection, but which are of too preliminary a character to merit inclusion in this Report, seemed to support this view.]

In the present Report records are given showing that *streptococci* presumably of intestinal origin pass through the coke-beds in practically unaltered numbers, and may be isolated from $\frac{1}{1000}$ c.c. or less of the effluents. And reasons are given which suggest somewhat strongly that if *streptococci* can resist the biological processes at work in the coke-beds there is small ground for believing that other germs of a dangerous kind, e.g., the typhoid bacillus, will be destroyed.

Further, it has been stated in this Report that although the products of the bacteria in the effluents are not fatal even when large doses are injected subcutaneously into guinea-pigs, the effluents plus the contained bacteria are decidedly pathogenic and do not indeed differ in this respect materially from the raw sewage.

[A local reaction is always observed, and abscess formation and ulceration frequently result from the injections, although they do not necessarily prove fatal. When death occurs rapidly, the fatal result seems to be usually due to virulent *B. coli* or *B. proteus* or *B. enteritidis sporogenes*, or to microbes more or less closely allied to these germs. Doubtless, however, other microbes are also concerned in producing a pathogenic effect. Sometimes the animal apparently recovers, but eventually dies from *pseudo-tuberculosis* (*B. pseudo tuberculosis*.)]

In the Supplement to the Second Report it was shown that the deposit accumulating on the coke in the bacterial beds contained the spores of *B. enteritidis sporogenes* in great abundance, and also that two mice inoculated subcutaneously each with a small portion of the deposit died with all the characteristic symptoms of *tetanus*. Further, "*acid-fast*" bacteria were present in considerable numbers in the deposit, and they were also found in the crude sewage and effluents—particularly in the latter. The inference would seem to be that the "*acid-fast*" bacteria are stored in the coke-beds, and are habitually or occasionally washed away in the effluents.

[Although many of these "*acid-fast*" bacteria could not with certainty be morphologically distinguished from the *tubercle bacillus*, it was not claimed that they were necessarily the microbe of *tuberculosis*, alive or dead, virulent or non-virulent. But it was pointed out as a significant fact that in one instance a guinea-pig inoculated with the deposit from a bacterial bed (not, however, one at Barking or Crossness), especially rich in these "*acid-fast*" bacteria, did die from *tubercular* infection, and that sections of its organs when appropriately stained showed the presence of numerous *tubercle bacilli*.]

In view of these results, only one conclusion seems possible, namely, that however satisfactory the process may be from the chemical and practical point of view, the effluents from the bacterial beds cannot be reasonably assumed to be more safe in their possible relation to disease than raw sewage slightly diluted, but otherwise unaltered in its bacterial composition.

VII—ADDENDA.

1.—THE VITALITY OF THE CHOLERA BACILLUS, *B. PRODIGIOSUS*, AND *STAPHYLOCOCCUS PYOGENES AUREUS* IN CROSSNESS CRUDE SEWAGE.

The sewage was not sterilised, as sterilisation greatly alters its chemical composition, and the object of the experiments was to ascertain broadly whether these germs survive for any length of time in competition with the numerous other micro-organisms normally present in raw sewage.

(a) VITALITY OF THE CHOLERA BACILLUS IN CROSSNESS CRUDE SEWAGE.

Experiment 1, October 24th, 1898.

10 c.c. of Crossness crude sewage were poured into a sterile test-tube, and the tube was plugged with sterile wool. The contents of the tube were next inoculated with a platinum loopful of the cholera bacillus taken from a young gelatine culture. The tube containing the crude sewage (+ the cholera bacillus) was kept in a dark cupboard at the room temperature. In seeking to determine the viability of Koch's vibrio the following plan was adopted. From time to time a loopful of the sewage was transferred to a tube containing sterile peptone solution (peptone 1 per cent.; NaCl 0·5 per cent.). The peptone tube was incubated at 37° C., and in less than twenty-four hours a loopful of the liquid was taken from near the surface and microscopic stained cover-glass preparations were made. A number of such preparations were made, and these were examined microscopically for the presence of Koch's vibrio.

The results obtained are shown in the following Table—

Date of inoculation of peptone solution.	Date of examination of peptone culture.	Descriptive number of cultures.	Remarks. Results of the examination of the peptone cultures.
1898. October 24 (Immediately after the inoculation of the sewage with Koch's vibrio.)	1898. October 25	(1)	Cholera vibrios present in great abundance and almost in pure culture.
October 25	„ 26	(2)	Vibrios could only be found after prolonged searching.
„ 26	„ 27	(3)	No difficulty was experienced in finding vibrios.
„ 27	„ 28	(4)	Vibrios present in abundance.
„ 28	„ 29	(5)	A positive result was with difficulty obtained.
„ 31	November 1	(6)	„ „
November 1	„ 2	(7)	„ „
„ 2	„ 3	(8)	„ „
„ 3	„ 4	(9)	„ „
„ 4	„ 5	(10)	A doubtfully positive result.
„ 9	„ 10	(11)	Only a few vibrios, but these were typical.
„ 18	„ 19	(12)	Many vibrios, but most of them larger (longer and thicker) than normal.
„ 24	„ 25	(13)	? Positive.
December 5	December 6	(14)	Quite negative.

It is to be noted that in culture (1) Koch's vibrio was present almost in pure culture, but in (2) it was demonstrated only with great difficulty. In (3) and (4), however, vibrios were present in abundance. In (5), (6), (7), (8), (9) cultures a positive result was arrived at only with great difficulty, and in (10) the result was only doubtfully positive. In (11) and (12) cultures the diagnosis was more certain, but in the latter culture the microbe seemed to have become slightly altered, morphologically. In (13) there was a considerable element of doubt, and in (14) the result was quite negative.

The apparent rise and fall in the vitality of the vibrio during the progress of the experiment is of interest.

It is evident that the cholera bacillus is able to exist in Crossness crude sewage in competition with the numerous other microbes also present and under laboratory conditions of experiment for a considerable time.

Experiment 2, October 26th, 1898.

The experiment was a repetition of experiment 1, except that a vastly greater number of cholera germs were added to the sewage, viz., the whole of the surface growth from an oblique agar culture incubated at 37° C. for three days. Indeed, the number of vibrios added was greatly in excess of the total number of micro-organisms in the sewage.

The results obtained were as follows—

Date of inoculation of peptone solution.	Date of examination of peptone culture.	Descriptive number of cultures.	Remarks. Results of the examination of the peptone cultures.
1898.	1898.		
October 26 (Immediately after the inoculation of the sewage with Koch's vibrio.)	October 27	(1)	Cholera vibrios present in great abundance.
October 27	" 28	(2)	A positive result was obtained only with difficulty.
" 28	" 29	(3)	Vibrios found without difficulty.
" 31	November 1	(4)	"
November 1	" 2	(5)	Only a few vibrios could be found.
" 2	" 3	(6)	A positive result was obtained without much difficulty.
" 3	" 4	(7)	Vibrios found without any difficulty.
" 4	" 5	(8)	A positive result was obtained but only after prolonged searching.
" 9	" 10	(9)	The result was negative.
" 18	" 19	(10)	" "
" 24	" 25	(11)	" "
December 5	December 6	(12)	" "

In this experiment, as in experiment 1, there was a difficulty experienced in finding the cholera bacillus in the peptone culture number (2) made only the day after inoculation. Yet in both experiments no difficulty was experienced in arriving at a positive diagnosis as regards number (3) peptone culture. Notwithstanding the enormous number of vibrios added to the sewage, they appeared to die out much sooner than in the preceding experiment.

Speaking in general terms, and dealing with both experiments, it may be said that under the above conditions of experiment the cholera bacillus may lose its vitality in less than a fortnight (experiment 2) or remain viable for nearly four weeks (experiment 1) when added to Crossness crude sewage.

(b) VITALITY OF *B. PRODIGIOSUS* IN CROSSNESS CRUDE SEWAGE.

Experiment 3, October 24th, 1898.

In this experiment 10 c.c. of Crossness crude sewage were inoculated with *B. prodigiosus* (platinum loopful from a young agar culture). Although this micro-organism is occasionally met with in sewage it is very rare in London raw sewage, and so is to be regarded as being in a sense an intruder. The tube containing the raw sewage (+ *B. prodigiosus*) was kept in a dark cupboard at the room temperature.

In seeking to determine the viability of this microbe in the sewage the following plan was adopted—From time to time a loopful of the sewage (+ *B. prodigiosus*) was taken and rubbed over the sloping surface of oblique agar tubes. These were kept at the room temperature, and the presence of *B. prodigiosus* was readily detected by the bright red colour produced by the growth of this microbe in agar cultivations.

The results obtained are shown in the following Table—

Date of inoculation of the oblique agar tubes.	Descriptive number of cultures.	Results. As regards red growth on oblique agar tubes.
1898.		
October 24 (Immediately after the inoculation of the sewage with <i>B. prodigiosus</i>).	(1)	Positive.
October 25	(2)	"
" 26	(3)	"
" 27	(4)	"
" 28	(5)	"
" 29	(6)	"
" 31	(7)	"
November 1	(8)	" (only a few colonies).
" 2	(9)	" "
" 3	(10)	" "
" 4	(11)	" "
" 5	(12)	" (only 3 colonies).
" 7	(13)	" (only 1 colony).
" 9	(14)	" "
" 12	(15)	Negative.
" 14	(16)	"
" 16	(17)	"
" 18	(18)	"
" 25	(19)	"
December 3	(20)	"

It is to be noted that *B. prodigiosus* retained its vitality in the crude sewage for sixteen days. Afterwards it could not be found in any of the cultures. During the sixteen days *B. prodigiosus* remained alive it was noted that whereas at the start an abundant red growth showed itself in the agar cultures towards the end of this period the number of red colonies developing was very small, and in cultures (12), (13), and (14) the number of red growths was only three, one, and one respectively. Speaking in general terms it may be said that the number of *B. prodigiosus* decreased rather rapidly, and usually each successive culture showed less red growth than the one immediately preceding it.

Experiment 4, November 2nd, 1898.

This experiment was a repetition of experiment 3, 10 c.c. of Crossness crude sewage being inoculated with a platinum loopful of a recent growth of *B. prodigiosus* on agar.

The results obtained are shown in the following table—

Date of inoculation of the oblique agar tubes.	Descriptive number of cultures.	Results. As regards red growth on oblique agar tubes.
1898.		
November 2 (Immediately after the inoculation of the sewage with <i>B. prodigiosus</i> .)	(1)	Positive.
November 3	(2)	"
" 7	(3)	"
" 9	(4)	" (only one colony).
" 12	(5)	"
" 14	(6)	Negative.
" 16	(7)	"
" 18	(8)	"
" 24	(9)	"
December 3	(10)	"

In this experiment the *B. prodigiosus* remained alive for 10 days, but was not discoverable on the 12th, 14th, 16th, 22nd, or 31st day after inoculation.

Speaking of both the experiments it may be said that *B. prodigiosus* either dies or becomes so reduced in numbers as to be no longer capable of being isolated in from about 10 to 16 days in Crossness crude sewage under the above laboratory conditions of experiment.

It would seem from these experiments as if the cholera bacillus was capable of existing in sewage for a longer time than the *B. prodigiosus*. Assuming, of course, that the two different methods used for detecting these microbes were of equal delicacy, which is probably not quite the case.

(c) VITALITY OF STAPHYLOCOCCUS PYOGENES AUREUS IN CROSSNESS CRUDE SEWAGE.

Experiment 5, November 9th, 1898.

In this experiment 10 c.c. of Crossness crude sewage were inoculated with a platinum loopful of a young agar culture of *staphylococcus pyogenes aureus*. This pathogenic microbe has been described as being occasionally present in raw sewage. My own experience leads me to believe that it is only very rarely present in sewage. Certainly it is to be regarded as a microbe foreign to the bacterial flora of ordinary sewage.

The tube containing the raw sewage (+ *St. pyogenes aureus*) was kept in a dark cupboard at the room temperature.

In seeking to determine the viability of this micro-organism in the sewage the following plan was adopted. From time to time a loopful of the sewage (+ *St. pyogenes aureus*) was taken and rubbed over the sloping surface of oblique agar tubes. These were incubated at 37° C., and the presence of *St. pyogenes aureus* was readily ascertained by the golden orange-yellow colour produced by the growth of this germ in agar cultures.

The results obtained are shown in the following Table—

Date of inoculation of the oblique agar tubes.	Descriptive number of cultures.	Results. As regards presence or absence of characteristic coloured growth of <i>St. pyogenes aureus</i> .
1898.		
November 9 (Immediately after the inoculation of the sewage with <i>St. pyogenes aureus</i> .)	(1)	Positive (decided growth)
November 10	(2)	"
" 11	(3)	"
" 12	(4)	"
" 14	(5)	"
" 17	(6)	"
" 24	(7)	"
December 3	(8)	"
" 14	(9)	Negative.
" 17	(10)	Positive (one colony).

In cultures made subsequent to December 17th, no colonies of *St. pyogenes aureus* could be found.

It is to be noted that up to the twenty-fourth day after the original inoculation the presence of *St. pyogenes aureus* was easily demonstrated. But a negative result was obtained in the case of culture (9)—thirty-fifth day. Nevertheless, in culture (10) a single colony was discovered, *i.e.*, on the thirty-eighth day subsequent to inoculation. Later, the microbe was no longer discoverable in cultures made from the sewage.

From this experiment it would seem that *St. pyogenes aureus* is capable of retaining its vitality in Crossness crude sewage for a considerable time.

In conclusion, and speaking in general terms of all the experiments, it may be stated that the cholera bacillus (pathogenic), *B. prodigiosus* (non-pathogenic), and *St. Pyogenes aureus* (pathogenic) are capable of retaining their vitality in Crossness crude sewage in competition with the very numerous bacteria normally present in the liquid for a considerable time. But it must be insisted upon that the conditions prevailing in laboratory test-tube experiments are widely different from those in operation in biological coke-beds. Nevertheless, and looking at the subject from the point of the epidemiologist, these experiments are far from reassuring, and, indeed, would seem to indicate that the antagonism of the saprophytic bacteria normally present in sewage would not suffice for the destruction of pathogenic species either in the sewers or, later, in the bacterial beds. Since the bacterial beds are purposely constructed so as not to mechanically hold back the suspended matters, and as it is to be feared from these experiments that the biological processes at work in the coke-beds would not rapidly destroy the life, although they might inhibit the multiplication of pathogenic germs accidentally introduced into the crude sewage, the effluents from the beds ought to be regarded as no more safe in their possible relationship to disease than the raw sewage itself. It must be remembered, however, that the number of the pathogenic germs added to the sewage in these experiments was vastly greater than could conceivably take place under natural conditions, and that, notwithstanding the enormous number introduced, there was definite indication of a somewhat rapid decrease in their numbers.

For records relating to the passage through the bacterial beds of pathogenic germs habitually or occasionally present in crude sewage reference must be made to other sections of this Report and also to previous Reports.

2.—THE INOCULATION OF THE 13-FOOT COKE-BED AT CROSSNESS WITH A SPECIAL SEWAGE MICROBE.

Most observers who have had any practical experience of the so-called biological treatment of sewage are agreed as to the necessity of treating *new* bacterial beds with small but gradually increasing doses of raw sewage until they have become thoroughly *matured*. Further, it is generally believed that a *mature* bed is one which has become by a natural process of selection *charged* with the special bacteria concerned in the work of purification. By varying the conditions in a number of ways changes, favourable or the reverse, may readily be induced. For example, by overtaxing the coke-beds a change commonly spoken of as “*sickenening*” may set in when the chemical results will no longer be satisfactory. In such a case it may be conjectured that the wrong kind of bacteria have gained the ascendancy. Conversely, by greatly diminishing the amount of sewage to be “*treated*,” a particularly good effluent may often be obtained. Here presumably the special bacteria are able to multiply abundantly and to exercise their specific qualities to the best advantage. Exactly which kind of bacteria are directly beneficial and which act as intruders is not yet clearly known, although the broad fact that putrefactive and nitrifying germs are necessary has long been established. Nor is it properly understood under what conditions the special bacteria should be placed in order to allow them to exercise their beneficial qualities to the best advantage. Bacterial processes so widely different as those which aim at encouraging the growth of aerobic micro-organisms and those which are essentially or largely anaerobic in character, have been put in operation by different workers. And each observer claims for his own process peculiar advantages. But it will be gathered from what has been said that probably all the bacterial processes in practical operation at the present time aim at allowing certain bacteria or groups of bacteria to gain the ascendancy by a *natural process of selection*.

Although this is certainly a rational method of “*treating*” sewage it is to be thought of that the future of the biological treatment of sewage may possibly lie in the direction of a real or apparent interference with nature’s methods. In the absence of absolute knowledge as to the exact conditions under which sewage should be placed so as either in one or a succession of stages to foster the growth of the bacteria directly concerned in the work of purification and to inhibit the growth of unnecessary or harmful germs it is conceivable that the addition (continuously or intermittently) of pure cultures in large amount of selected microbes might exercise a beneficial effect. Which kinds of bacteria should be added, and under what conditions, cannot safely be affirmed in the present state of our knowledge. The experiments might be conducted so as to aid or abet nature rather than with the object of interfering with or upsetting the natural order of things, and they might occupy several stages. Further, they might be carried out in connection with bacterial beds already for some time in operation or new beds might be sown with special bacteria previous and preparatory to the application of sewage. It is conceivable that they might be divided into two stages—the first aerobic or semi-anaerobic, the bacteria used belonging to the class of putrefactive aerobes and facultative anaerobes, and the second stage purely aerobic, the micro-organisms involved in the process being those of nitrification, or, preliminary to the above, and as an initial stage anaerobic bacteria might be employed. Lastly, the experiments might be conducted from the epidemiological point of view rather than with the sole idea of obtaining an effluent chemically sound. For as it is known that certain micro-organisms are antagonistic to others, the special bacteria selected might be saprophytes, the products of whose growth act as bactericidal agents to pathogenic germs.

Of course it will be argued that nature’s own methods are the best, and that any interference with the natural course of events is not to be recommended, and that it would be wise to first determine more accurately the precise functions of the different bacteria concerned in the work of

the purification of sewage before proceeding to add special bacteria to a liquid or to a bacterial bed already harbouring all the known microbes of putrefaction and nitrification.

Such contentions are certainly justifiable, but it is to be thought of that the path to knowledge does not always lie along the most direct route, and accident has before now revealed the truth where experiments conducted on apparently sound lines have entirely failed.

Although, as regards the so-called biological treatment of sewage, the results obtained in the past have been most encouraging, at all events, from the chemical point of view, it is now clearly established that all the different processes which have been tried, suffer from serious limitations which at the present time seem almost insuperable in character.

It is conceivable that both from the practical and epidemiological point of view a solution of the problem of sewage disposal may lie in one or other of the directions that has been indicated.

The stress of work involved in the periodical examination of the crude sewage and effluents from the coke-beds made it impossible to carry out any prolonged research of the above nature.

Nevertheless, one experiment was tried, and although attended with apparently negative results, its description will not be out of place.

It will be remembered that in previous Reports it was shown that a rapidly-liquefying gas-forming proteus-like germ was present in London crude sewage in numbers usually exceeding 100,000 per c.c. This microbe was also found to be present in the effluents in very large numbers. Its ability to form gas, its rapid peptonising action and its abundance seemed to indicate that it was possibly a microbe specially concerned in the work of purification. Accordingly it was determined to isolate a strain of this micro-organism from an effluent, to cultivate it on a large scale, and to add it in great amount to the crude sewage during the ordinary process of filling a matured coke-bed.

Three strains of "*sewage proteus*"* were isolated from 1000 c.c. of Barking primary B effluent, (December 6th, 1899). They all grew luxuriantly at blood-heat, formed gas in twenty-four hours in gelatine shake cultures, liquefied gelatine very rapidly, and were very motile. One proved virulent when injected into a guinea-pig; another produced a strong local reaction, but the animal recovered, while the third was apparently non-pathogenic. The latter microbe was used in the experiment.

700 c.c. of agar were added to about 70 tubes and sterilised. The agar was allowed to solidify obliquely in the test tubes. The tubes were next inoculated with the "*sewage proteus*" and incubated at 20° C.

The growth from each of the tubes was transferred to sterile bouillon (1,500 c.c.), and the mixture of bacteria and broth used to inoculate the crude sewage as it flowed on to the 13-foot coke-bed at Crossness. This meant the addition of billions of *B. proteus* to the sewage.

The experiment was carried out in the following way—

On December 19th, 1899, the bacterial mixture (1,500 c.c.) was added to the crude sewage (about 6,000 gallons) as it flowed on to the coke-beds, the addition being made in small quantities at a time, so as to cover the whole of the period occupied in filling the bed, namely, about twenty minutes.

The bed was allowed to remain full for the usual period, namely, three hours, and it was emptied in the usual manner.

During the process of emptying, and especially during the first flow of the effluent, a number of vessels in bulk representing approximately thirty gallons—were filled with the effluent and kept in a warm place.

When the time arrived for filling the coke-bed again the contents of the vessels were added to the sewage flowing on to the bed.

Further, when, after the usual period, the bed was again emptied, the vessels were again filled with the first flow of the effluent.

The above series of operations was carried out until December 22nd, i.e., the crude sewage (about 6,000 gallons) as it flowed on to the coke-bed was first charged on December 19th with a mixture of *B. proteus* and broth (1,500 c.c.) (the microbes being present in number inconceivably great), and subsequently on six other consecutive occasions with the first flow of the effluent from the previous emptying of the coke-bed.

Most unfortunately at this period circumstances arose which made it impossible to test the value of the experiment from the biological point of view. This is greatly to be regretted, as it would have been of interest to have known if *B. proteus* was more numerous in the effluent than normally, and, if so, how long such numerical superiority was maintained. Further, whether its presence exercised any inhibiting influence on any of the other bacteria usually found in the crude sewage and effluents.

Mr. Biggs, the chemist in charge at the Southern Outfall Works, kept careful notes during the above period. He was unable either from the chemical or practical point of view to arrive at any other conclusion than that the experiment yielded quite negative results. That is to say the inoculation of the coke-bed with *B. proteus* did not produce any appreciable alteration in the effluent either as regards its chemical composition or physical appearance. Nor was the capacity of the coke-bed increased. The negative results may have been more apparent than real. Possibly if the effluents had been tested bacteriologically well defined changes might have been observed in the bacterial composition of the liquid extending over a longer or shorter period. It is conceivable also that if *B. proteus* had been added in still greater amount and for a longer period totally different results might have been obtained. To overcome the biological equilibrium of a mature coke-bed of the large capacity of the 13-foot bed at Crossness would naturally call for the addition of an enormous number of micro-organisms.

In conclusion, it must be insisted upon that the apparently negative character of this single experiment in no way suggests the advisability of abandoning a research carried out on the lines that have been here briefly indicated.

* The morphological and biological characters of "*sewage proteus*" have been already described. See Second Report, V. 3, page 36.

3.—THE EFFECT, AS REGARDS THE RESULTANT QUALITY OF THE EFFLUENTS FROM THE BACTERIAL BEDS, OF THE ADDITION OF CERTAIN CHEMICAL SUBSTANCES TO THE BARKING CRUDE SEWAGE.

It is known that some species of micro-organisms act with great vigour in the presence of a large excess of certain basic substances. For example, the nitrifying germs show increased bacterial activity when grown in liquid media containing an excess of magnesium or calcium carbonate. It is supposed that the solid grains besides neutralising the products of bacterial activity, act as what may be termed "contact points," enabling the bacteria to localise and concentrate themselves at a multitude of different spots. Further, if the liquid is in motion the grains may act as "carriers" of the microbes and their products from one place to another.

It is a matter of controversy among those who have practical concern with bacterial beds which is the best material to use. Some assert that the actual chemical composition of the substance is of no importance, that it is the physical qualities (e.g., whether smooth or jagged, pervious or impervious) of the material which is all essential. Others believe that certain substances are preferable to all others in virtue of their ability of exerting a basic action on the products of bacterial growth and of encouraging the active growth of special micro-organisms. However this may be, it is of interest to note that Mr. E. Brooke Pike, the chemist in charge at Barking, suggested the trial of ragstone as a better material in respect of its chemical composition than coke. This was agreed to by Dr. Clowes, and accordingly a trial was made of the comparative values of ragstone and coke bacterial beds. The outcome of these experiments seemed to be that the ragstone coke-beds did encourage the growth of the nitrifying germs (as evidenced by an increased production of oxidised nitrogen), but that the effluents, as regards the removal of dissolved oxidisable and putrescible matter, were not so satisfactory from the ragstone as from the coke-beds.

Although it is quite conceivable that the actual chemical composition of the material in a bacterial bed, quite apart from its physical characters, may play a definite part in influencing the biological processes at work in the bed, it is evident that the action, whatever it may be, cannot be expected to persist for an indefinite period.

With this idea in view, I suggested the trial of the artificial addition, in small amounts, of some such substance as magnesium carbonate or calcium carbonate to the sewage as it flowed on to the beds, as likely to produce a beneficial effect by its diffusion throughout the liquid in the beds and also by its settling on the surface of the fragments of coke and effecting a lodgement there. It was hoped that not only would the result be immediately beneficial, but that the good effect would be maintained for a considerable period after the addition of the substance had been abandoned. In short, that it would only be necessary to occasionally and very rarely resort to such an artificial measure in order to obtain uniformly good results. With Dr. Clowes' permission Mr. E. Brooke Pike was good enough to carry out some very careful experiments in this direction.

In the first series of experiments he added magnesium carbonate emulsion to the crude sewage as it flowed on to the beds in such strength as to correspond to 0·001 part of magnesium carbonate to every 100 parts of raw sewage.* This was done each time the beds were filled, viz., twice a day between Wednesday, 21st March, and Wednesday, March 28th, 1900, both days inclusive.

The results as regards oxidised nitrogen and oxygen absorbed from permanganate were as follows—

OXYGEN ABSORBED FROM PERMANGANATE IN FOUR HOURS AT 80° F. Parts per 100,000.

	Crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B.
Average of determinations made on March 7, 8, 9, 10, 12, 13, 14, 16, 19, 20, 1900.					
<i>Before the addition of magnesium carbonate</i>	6·740	3·410	2·280	3·420	1·780
Purification	—	49·4 per cent.	66·2 per cent.	49·3 per cent.	73·6 per cent.
Average of determinations made on March 21, 22, 23, 24, 26, 27, 28, 1900.					
<i>During the addition of magnesium carbonate</i>	7·343	3·460	2·429	3·343	1·886
Purification	—	52·9 per cent.	66·9 per cent.	54·5 per cent.	74·3 per cent.
Increase in purification	—	3·5 per cent.	0·7 per cent.	5·2 per cent.	0·7 per cent.

NITROGEN AS NITRATES.

Average of determinations made on March 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 19, 20, 1900.					
<i>Before the addition of magnesium carbonate</i>	—	·3726	1·2113	·3334	2·0238
Average of determinations made on March 21, 22, 23, 24, 26, 27, 28, 1900.					
<i>During the addition of magnesium carbonate</i>	—	·4469	1·1854	·4439	2·3935
Increase in amount of oxidised nitrogen	—	+19 per cent.	—2 per cent.	+33 per cent.	+18 per cent.

* This minimal quantity (·001 per cent.) was used as a preliminary, as it did not seem desirable to materially increase the suspended matters in the sewage.

It will be noted that all the beds showed a very slight but still an appreciable improvement as regards removal of dissolved oxidisable matter, presumably as the result of the magnesium carbonate treatment. Thus the increase in purification in the different effluents was 3·5 per cent.; 0·7 per cent.; 5·2 per cent.; 0·7 per cent.

The figures as regards oxidised nitrogen were more encouraging. Thus, with the exception of the secondary coarse bed (series A), where there was a decrease equal to 2 per cent., all the other effluents showed a definite increase of nitrates amounting to 19, 33, and 18 per cent. respectively as regards the effluents from the primary coarse bed (series A), the primary coarse bed (series B), and the secondary fine bed (series B).

In a sense there was a double gain as a result of the treatment, because the effluents contained a slightly smaller amount of putrescible matter and also carried with them into the river a greater amount of an oxidising substance.

But while the results are of considerable interest from the scientific point of view as affording some confirmation of theoretical considerations, it can hardly be said that they are of equal importance from the practical point of view. They do not, in short, indicate the advisability of continuing the addition of magnesium carbonate as a measure of *practical utility*.

In the second series of experiments Mr. E. Brooke Pike added, as well as magnesium carbonate, a like quantity (viz., '001 per cent.) of sodium carbonate.

Without entering into detail, it may be said that the results were no longer satisfactory, and indeed showed a general decrease in respect of nitrate production and of removal of dissolved oxidisable matter. The amount of sodium carbonate added was presumably too small to inhibit bacterial growth, and it is difficult to explain the falling off in the results, unless it be assumed that the sodium carbonate actually increased the vital activity of the micro-organisms in general, but in particular of the de-nitrifying germs and those specially concerned in producing putrefactive changes.

In conclusion, it may be said that further and more prolonged experiments seem desirable with magnesium carbonate and calcium carbonate, as well as with other substances. These might be tried in varying amounts and added continuously or intermittently. The experiments, of course, which have been described were merely of a tentative character. They may serve, however, to indicate a line of inquiry, not devoid of scientific interest and possibly of practical importance, which has hitherto been neglected.

PLATE I.

FIG. 1. *Streptococcus* X.—MICROSCOPIC PREPARATION FROM A BROTH CULTURE. 24 HOURS' GROWTH AT 38° C. STAINED BY GRAM'S METHOD. ISOLATED FROM $\frac{1}{1000}$ C.C. OF EFFLUENT FROM THE 6-FOOT SECONDARY COKE-BED AT CROSSNESS. X 1,000.

FIG. 2. *Streptococcus* XIX.—MICROSCOPIC PREPARATION FROM A BROTH CULTURE. 48 HOURS' GROWTH AT 38° C. STAINED BY GRAM'S METHOD. ISOLATED FROM $\frac{1}{1000}$ C.C. OF EFFLUENT FROM THE PRIMARY COARSE BED (SERIES A) AT BARKING. X 1,000.

FIG. 3. *Streptococcus* XX.—MICROSCOPIC PREPARATION FROM A BROTH CULTURE. 48 HOURS' GROWTH AT 38° C. STAINED BY GRAM'S METHOD. ISOLATED FROM $\frac{1}{1000}$ C.C. OF EFFLUENT FROM THE SECONDARY COARSE BED (SERIES A) AT BARKING. X 1,000.

FIG. 4. *Streptococcus* XXI.—MICROSCOPIC PREPARATION FROM A BROTH CULTURE. 48 HOURS' GROWTH AT 38° C. STAINED BY GRAM'S METHOD. ISOLATED FROM $\frac{1}{1000}$ C.C. OF BARKING CRUDE SEWAGE. X 1,000.



Fig. 1.



Fig. 2.



Fig. 3.



Fig. 4.



Fig. 5.

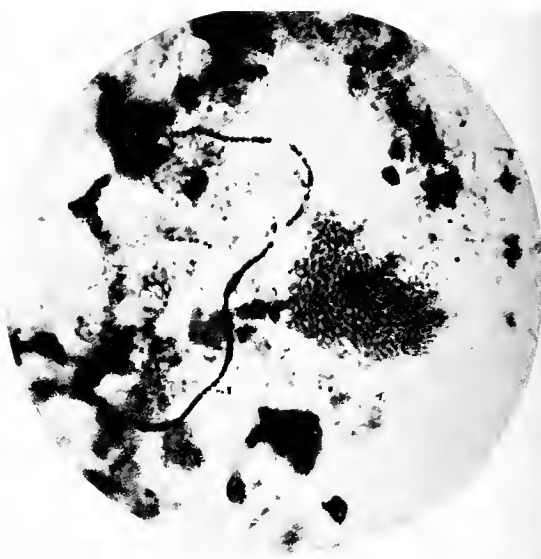


Fig. 6.

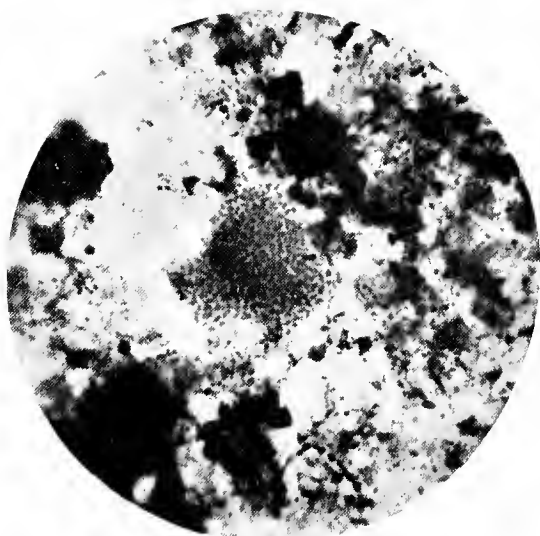


Fig. 7

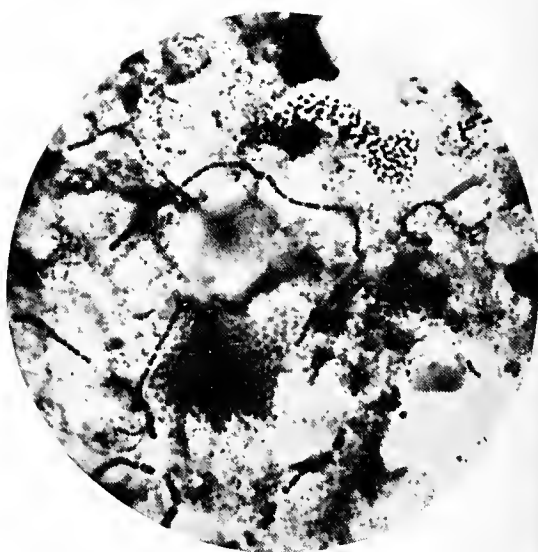


PLATE II.

FIG. 5. *B. Pyocaneus*.—MICROSCOPIC PREPARATION FROM AN AGAR CULTURE. 24 HOURS' GROWTH AT 38° C. ISOLATED FROM $\frac{1}{1000}$ C.C. OF THE EFFLUENT FROM THE SECONDARY COARSE BED (SERIES A) AT BARKING. X 1,000.

FIGS. 6, 7 AND 8. *Deposit Crossness crude sewage*.—50 C.C. OF THE RAW SEWAGE WERE CENTRIFUGALISED AND A MICROSCOPIC PREPARATION MADE OF THE DEPOSIT. THIS WAS WASHED IN ACID, THEN IN WATER, AND FINALLY STAINED WITH METHYLENE BLUE. IT SHOWS ZOOGLEA-LIKE MASSES OF COCCI AND CHAINS OF COCCI (STREPTOCOCCI). [IN THE SUPPLEMENT TO THE SECOND REPORT IT WAS STATED (PAGE 5) THAT—"NUMEROUS PREPARATIONS SUBSEQUENTLY MADE SHOW THAT EITHER COCCI, OR RODS SO SHORT AND ROUNDED AT THEIR ENDS AS TO SIMULATE COCCI, PREDOMINATE IN MICROSCOPIC STAINED SPECIMENS MADE FROM SEWAGE AND EFFLUENTS, AND NOT, AS MIGHT HAVE BEEN IMAGINED, DISTINCT BACILLARY OR ROD-SHAPED FORMS."] X 1,000.

PLATE III.

FIG. 9. *B. Thermophilus* (OR ALLIED FORM).—MICROSCOPIC PREPARATION FROM A BROTH CULTURE. ISOLATED FROM BARKING CRUDE SEWAGE. IN ILLUSTRATION OF ONE OF THE THERMOPHILIC BACTERIA—THESE MICROBES ARE ABUNDANT IN THE RAW SEWAGE AND IN THE EFFLUENTS FROM THE COKE-BEDS, AND GROW LUXURIANTLY AT A TEMPERATURE OF 60–70° C. X 1,000.

FIG. 10. SAME AS FIG. 9. X 500.



Fig. 9.



Fig. 10.

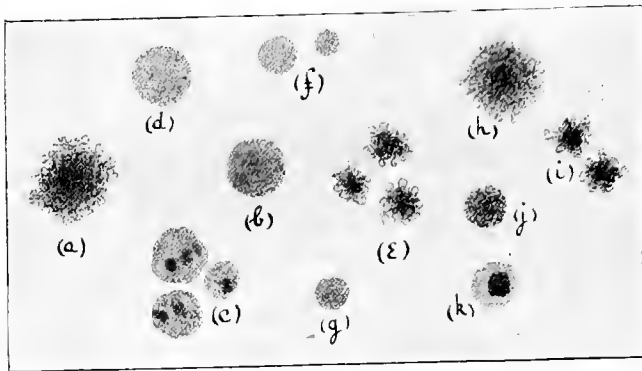


Fig. A.

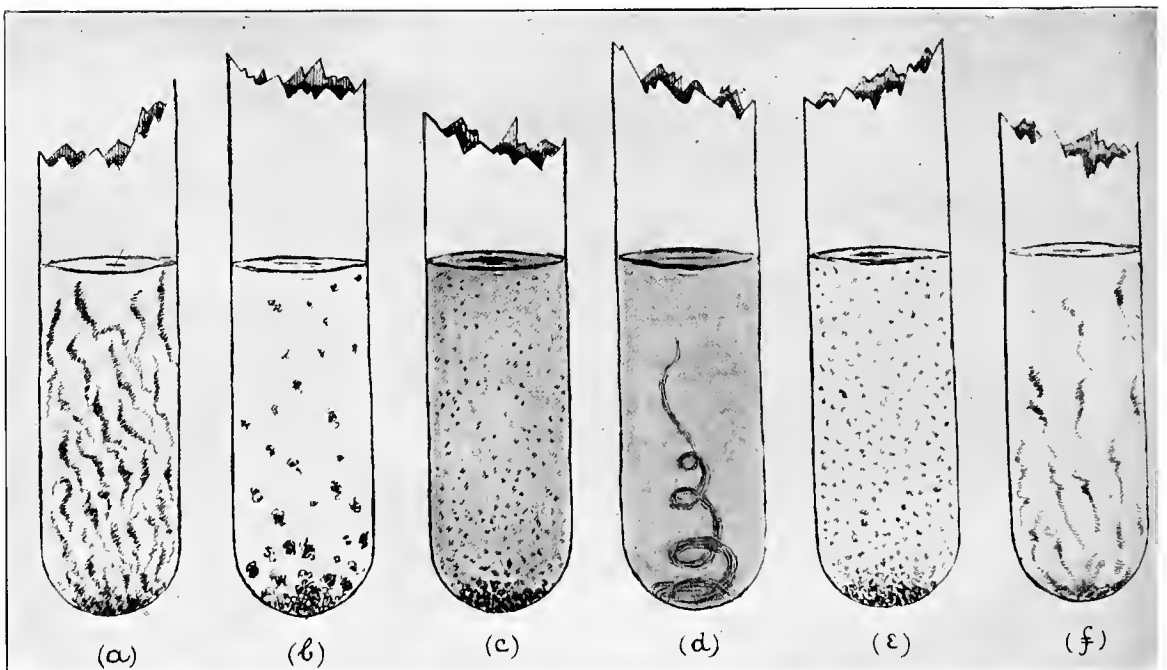


Fig. B.

PLATE IV.

FIG. A.

Colonies of Streptococci in gelatine and agar plate cultures.—UNDER A LOW POWER OF THE MICROSCOPE (LEITZ, 3 OBJECTIVE, 1 OCULAR.)

(DIAGRAMMATIC.)

- (a) STREPTOCOCCUS I. COLONY IN AGAR PLATE.
- (b) „ II. COLONY IN AGAR PLATE.
- (c) „ II. COLONIES IN OLD GELATINE CULTURE.
- (d) „ III. COLONY IN AGAR PLATE.
- (e) „ X. COLONIES IN AGAR PLATE.
- (f) „ XI. COLONIES IN GELATINE PLATE.
- (g) „ XII. COLONY IN GELATINE PLATE.
- (h) „ XIII. COLONY IN AGAR PLATE.
- (i) „ XIII. COLONIES IN GELATINE PLATE.
- (j) „ XIV. COLONY IN GELATINE PLATE.
- (k) „ XVIII. COLONY IN GELATINE PLATE.

FIG. B.

Broth and gelatine (incubated at blood heat) cultures of streptococci.

(DIAGRAMMATIC.)

- (a) STREPTOCOCCUS I. GELATINE CULTURE INCUBATED AT 37° C. FOR 2 DAYS.
 - (b) „ I. OLD BROTH CULTURE (SHAKEN UP).
 - (c) „ II. GELATINE CULTURE INCUBATED AT 37° C. FOR 2 DAYS.
 - (d) „ II. BROTH CULTURE (SHAKEN).
 - (e) „ IV. GELATINE CULTURE, 24 HOURS AT 37° C.
 - (f) „ XVII. BROTH CULTURE, 2ND DAY AT 37° C.
-

PLATE V.

FIG. C.

(DIAGRAMMATIC.)

COLONIES (*superficial and deep*) OF SPORE-FORMING ANAËROBES IN AGAR PLATE CULTURES (PREVIOUSLY INOCULATED WITH $\frac{1}{10}$ C.C. OF CRUDE SEWAGE OR OF EFFLUENT AND THEN HEATED TO 80° C. FOR 10 MINUTES: CULTIVATED UNDER ANAËROBIC CONDITIONS AT 37° C.). UNDER A LOW POWER OF THE MICROSCOPE (LEITZ, 3 OBJECTIVE, 1 OCULAR).

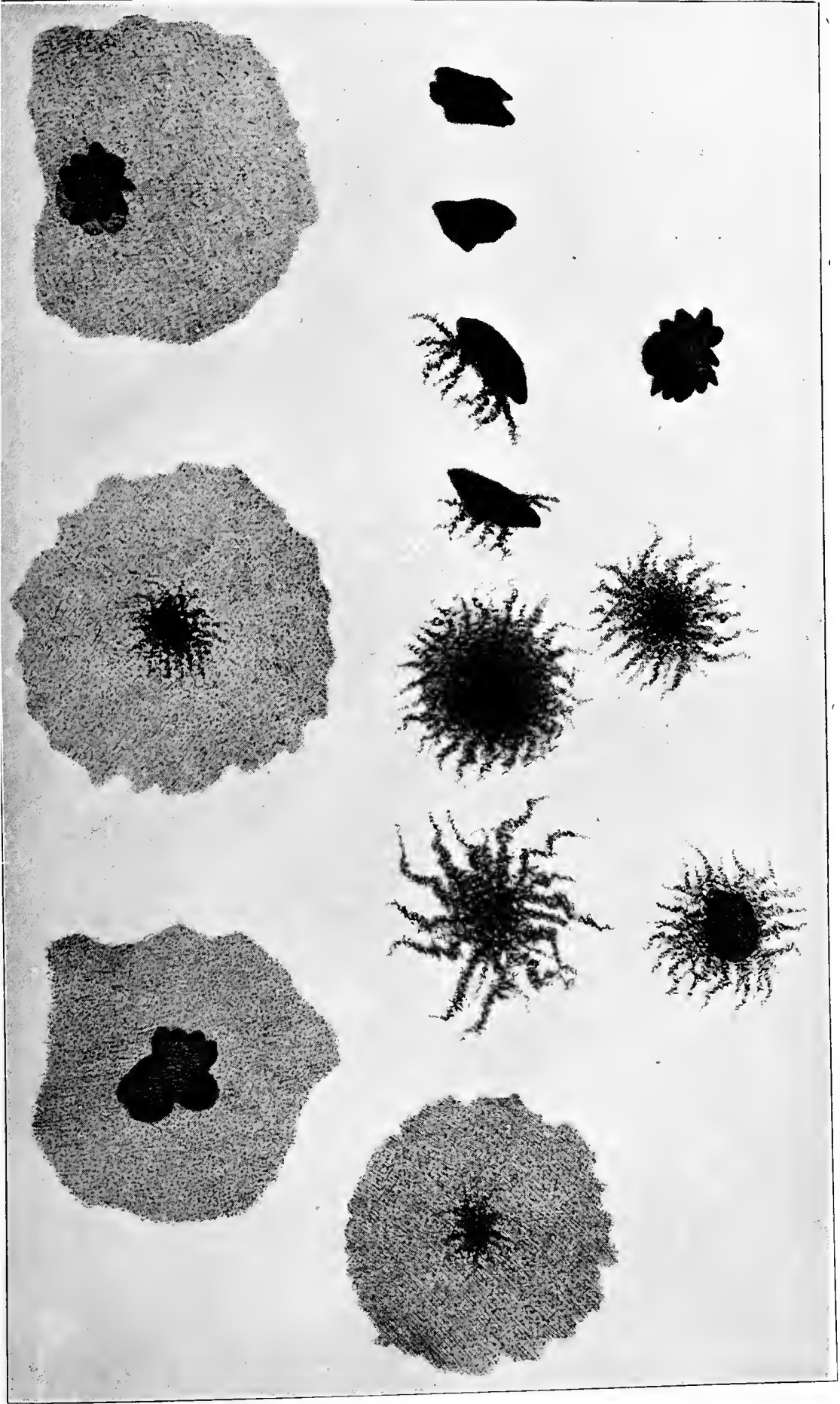
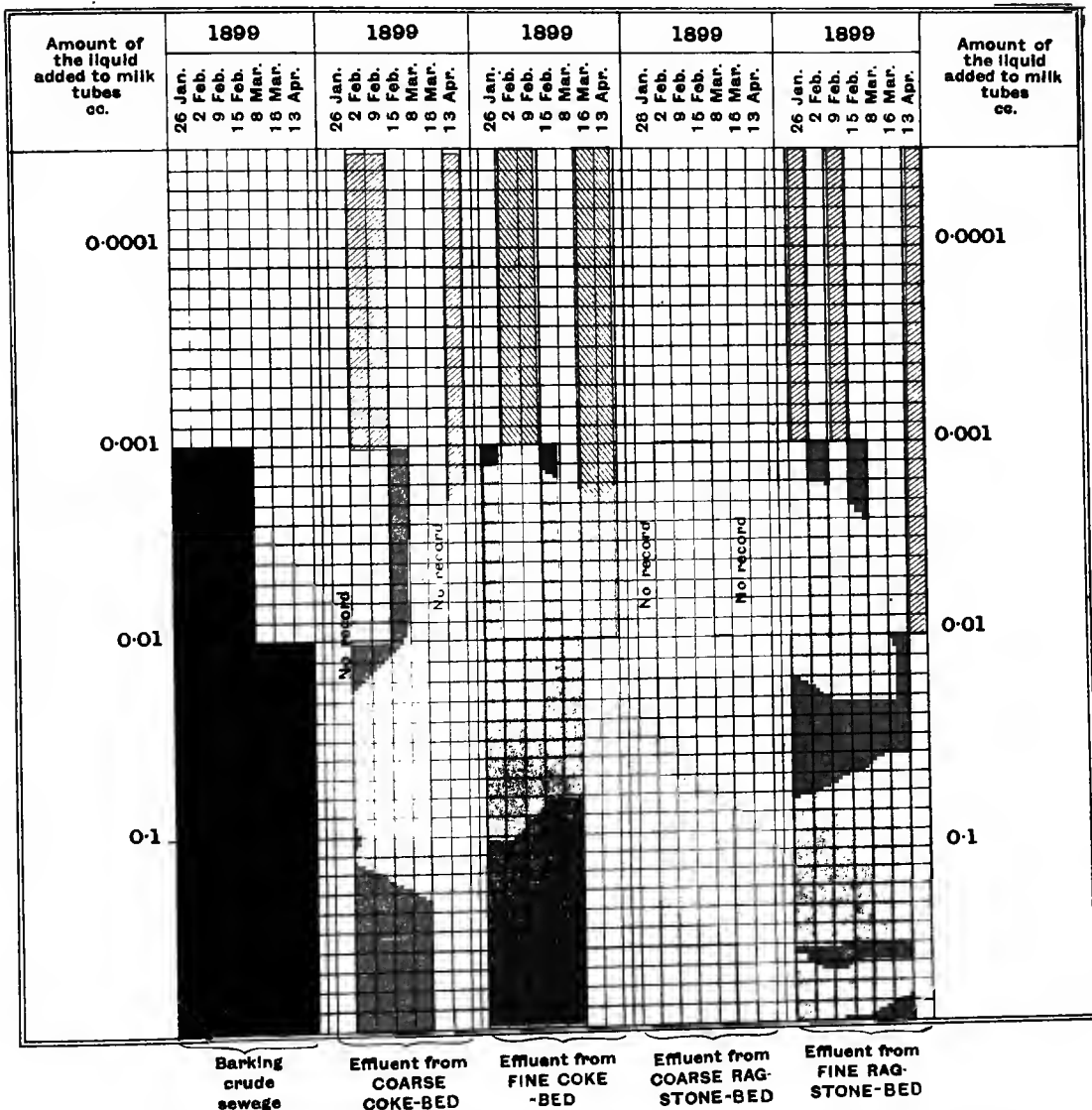


Fig. C.

DIAGRAM I.

Showing the number of spores of *Bacillus Enteritidis Sporogenes* in Barking crude sewage and in the effluents from the coarse and fine coke-beds, and also in the effluents from the coarse and fine ragstone-beds.



The "upward" columns refer to the SMALLEST amount of the liquid yielding a POSITIVE result as regards *Bacillus Enteritidis Sporogenes* when inoculated into milk tubes.

The "downward" columns refer to the LARGEST amount of the liquid yielding a NEGATIVE result as regards *Bacillus Enteritidis Sporogenes* when inoculated into milk tubes.

DIAGRAM 2.

Showing the total number of Bacteria in 1 cc of Barking crude sewage and in 1 cc of the effluents from the primary & secondary coarse beds (Series A); and the primary coarse bed and secondary fine bed (Series B).

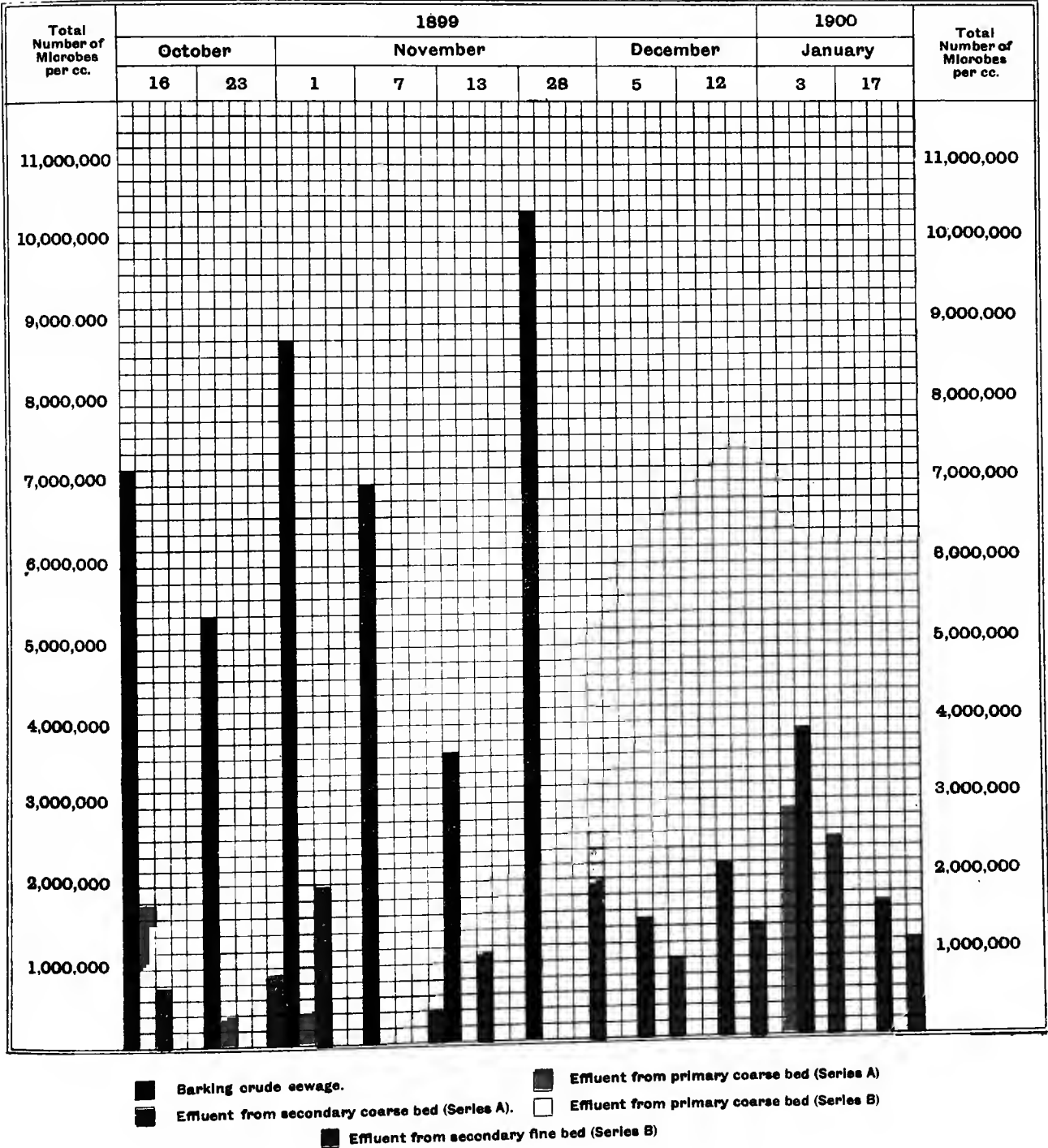


DIAGRAM 3.

Showing the number of *Bacillus Coli* (or closely allied forms) in 1 cc of Barking crude sewage, and in 1 cc. of the effluents from the primary and secondary coarse beds (Series A); and the primary coarse bed and secondary fine bed (Series B).

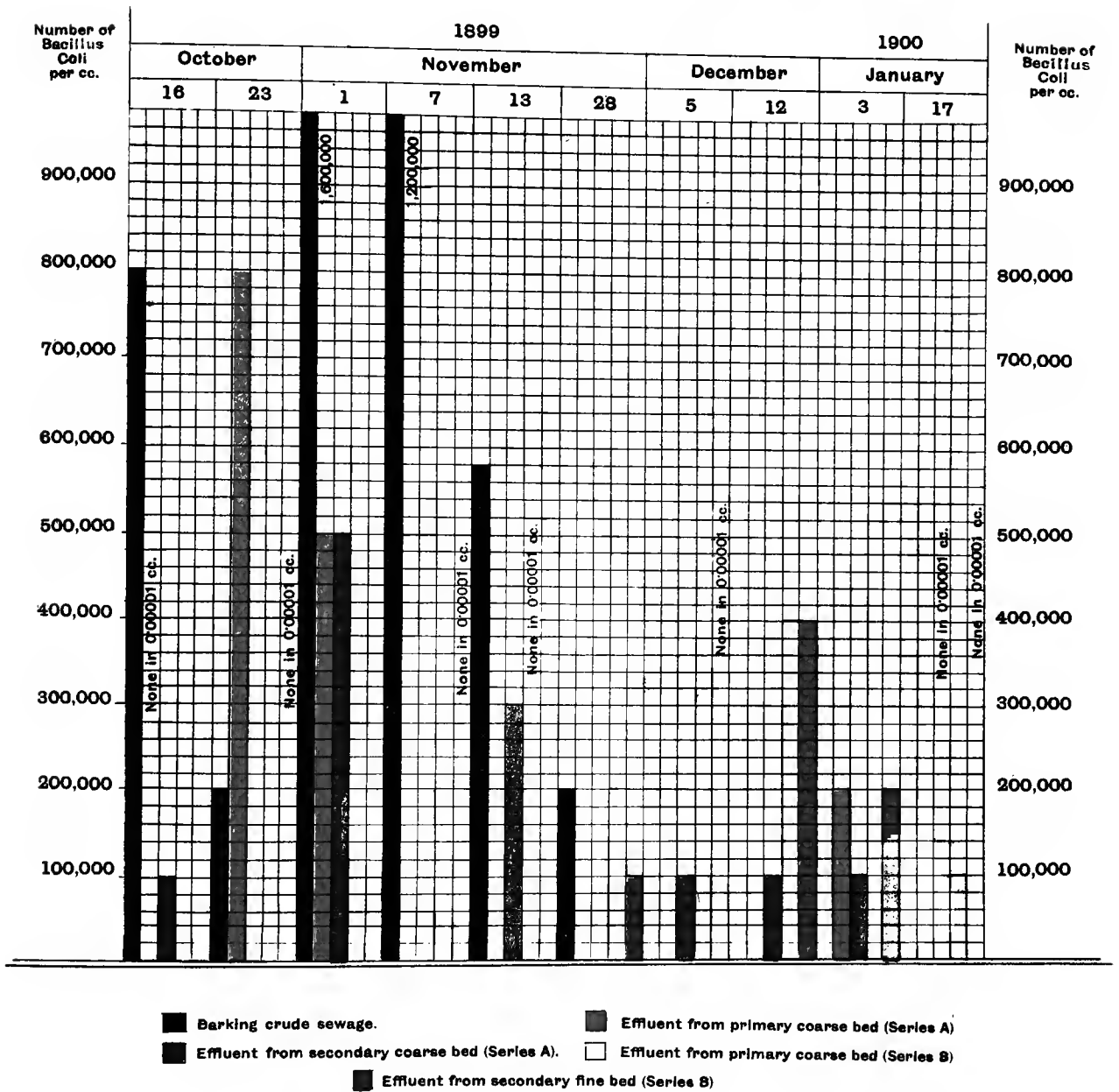
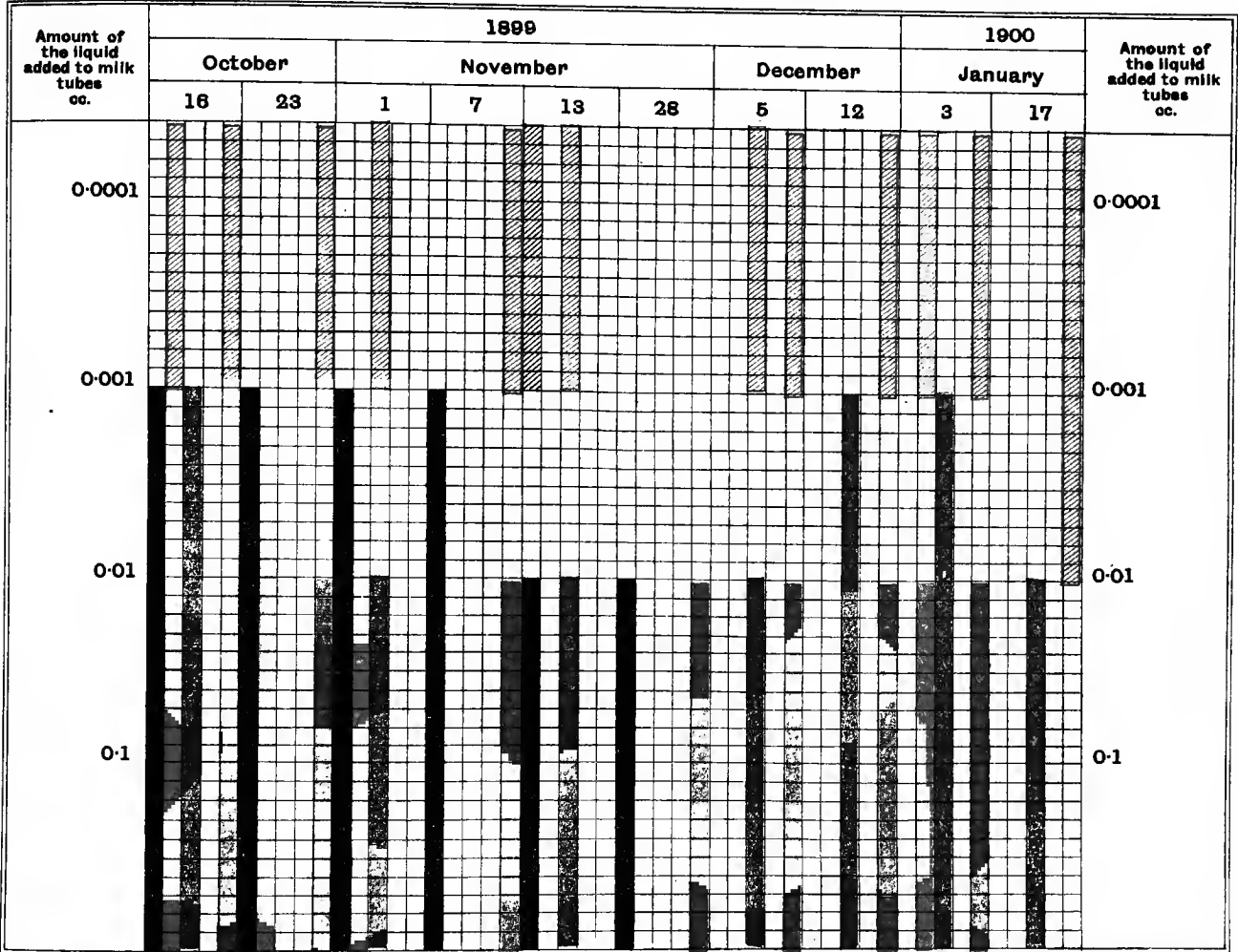


DIAGRAM 4.

Showing the number of spores of *Bacillus Enteritidis Sporogenes* in Barking crude sewage and in the effluents from the primary and secondary coarse beds (Series A); and the primary coarse bed and secondary fine bed (Series B).

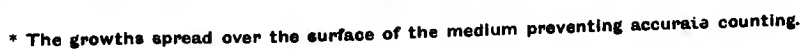


- Barking crude sewage.
- Effluent from primary coarse bed (Series A)
- Effluent from secondary coarse bed (Series A).
- Effluent from primary coarse bed (Series B)
- Effluent from secondary fine bed (Series B)

The "upward" columns refer to the SMALLEST amount of the liquid yielding a POSITIVE result as regards *Bacillus Enteritidis Sporogenes* when inoculated into milk tubes.

The "downward" columns refer to the LARGEST amount of the liquid yielding a NEGATIVE result when inoculated into milk tubes.

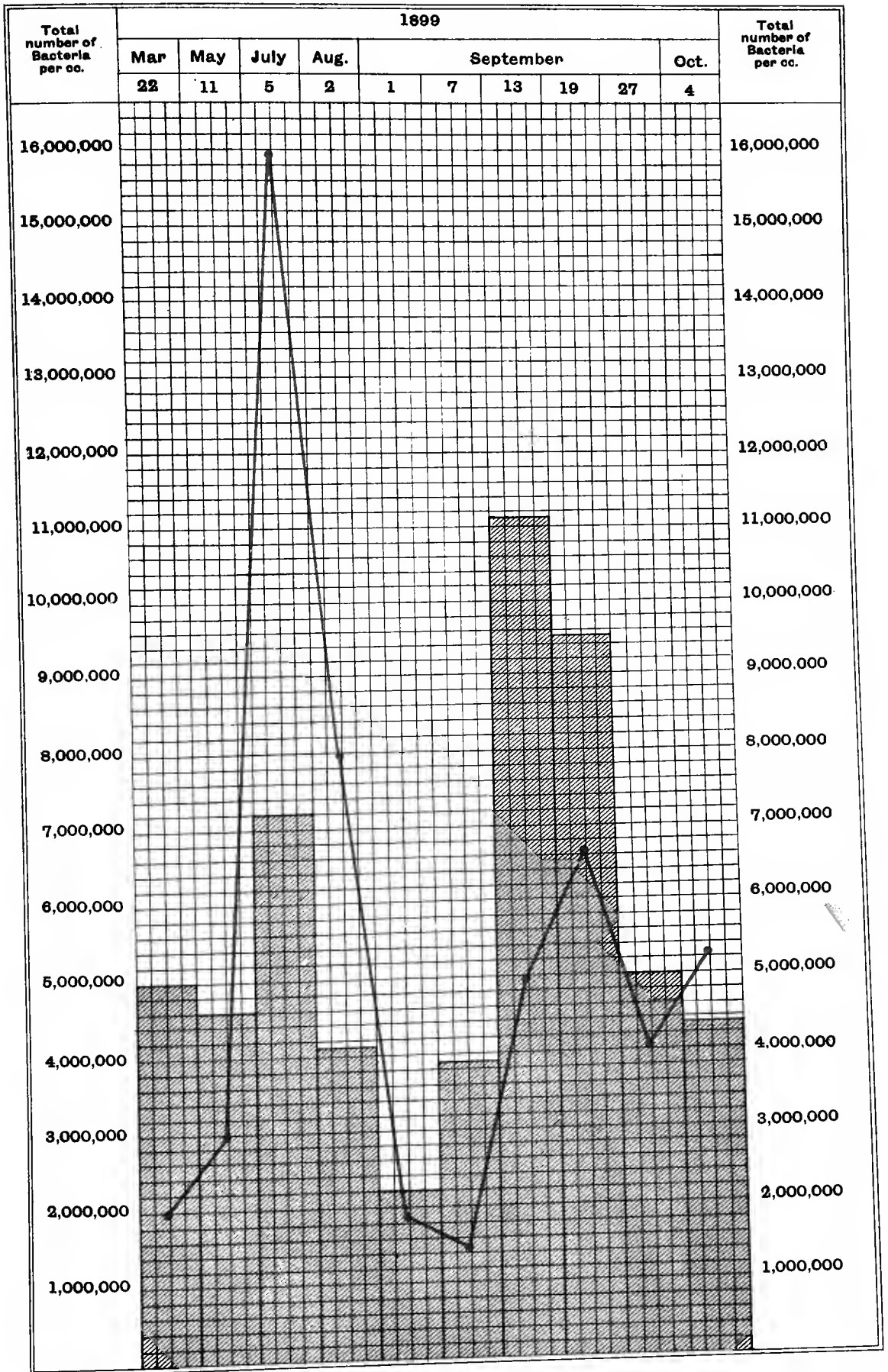
Showing the number of spores of Anaërobic Bacteria in 1 cc. of Crossness crude sewage and in 1 cc. of the effluent from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds. [Agar at 37° C].



* The growths spread over the surface of the medium preventing accurate counting.

DIAGRAM 6.

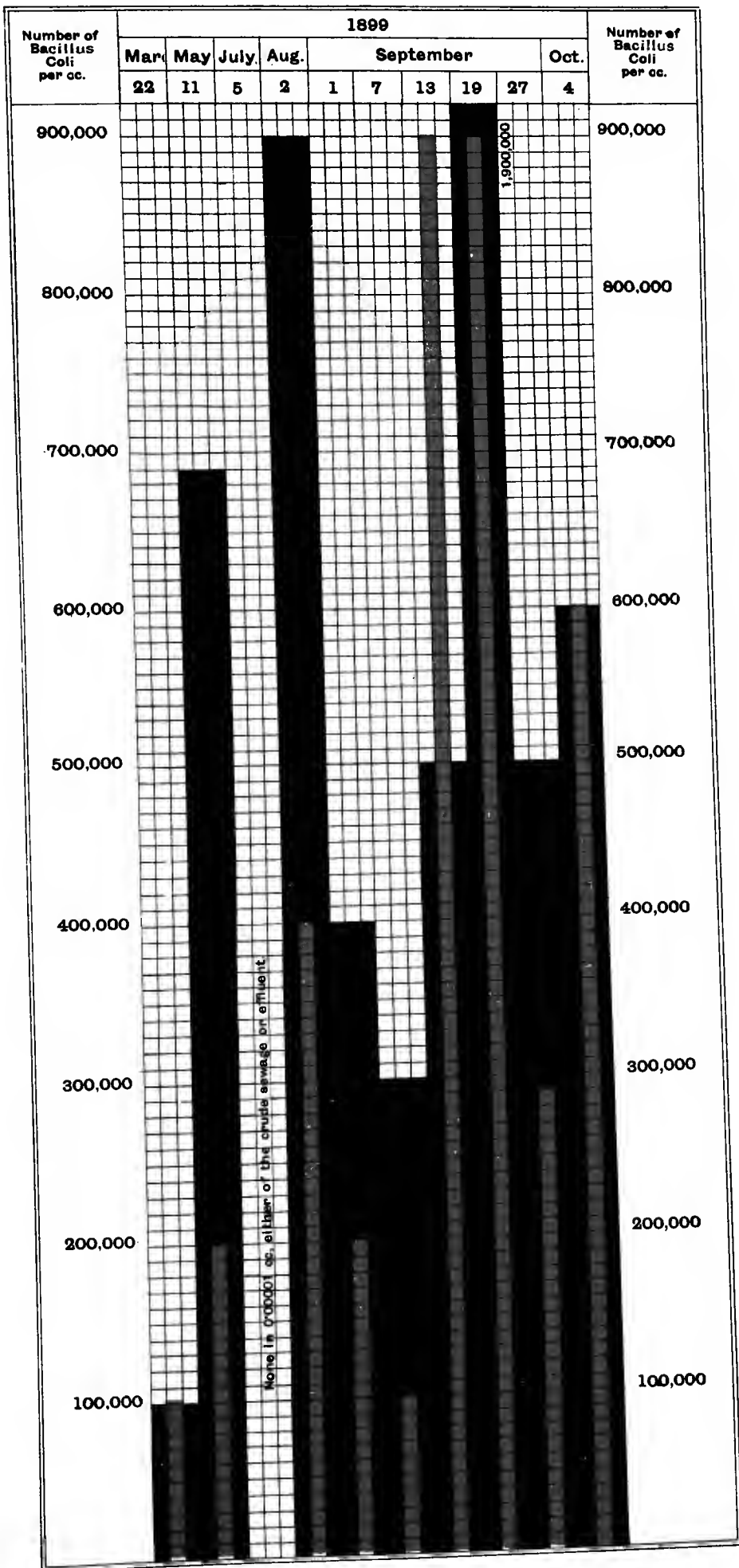
Showing the total number of Bacteria in 1 cc. of Crossness crude sewage, and in 1 cc. of the effluent from the 13 ft. coke-bed.



Crossness crude sewage. ——— Effluent from 13 ft. coke-bed.

DIAGRAM 7.

Showing the number of *Bacillus Coli* (or closely allied forms) in 1 cc. of Crossness crude sewage, and in 1 cc. of the effluent from the 13 ft. coke-bed.



■ Crossness crude sewage.

■ Effluent from the 13 ft. coke-bed.

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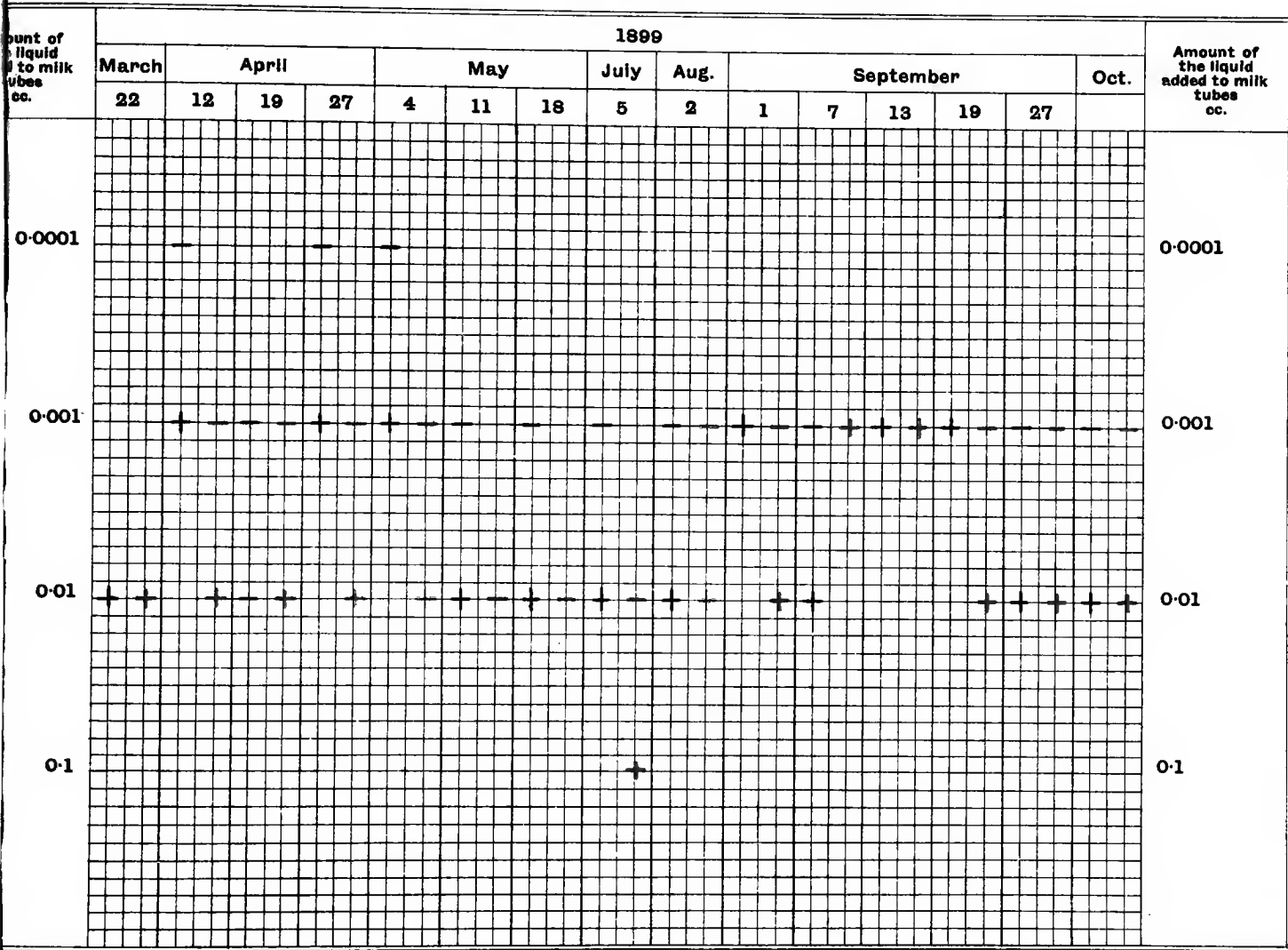
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DIAGRAM 8.
 Showing the number of spores of *Bacillus Enteritidis Sporogenes* in Crossness
 crude sewage, and in the effluent from the 13 ft. coke-bed.



The sign + signifies the presence, and the sign — the absence, of the spores of *Bacillus Enteritidis Sporogenes*.

+
— = Crossness crude sewage.

+
— = Effluent from 13 ft. coke-bed.

DIAGRAM 9.

Showing the total number of Bacteria (Gelatine at 20° C., Agar at 37° C.) in Crossness crude sewage, and in the effluent from the 13 ft. coke-bed.

